MASTER

Prototypes as final product
a practical method for profitable systems manufacture

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Eindhoven University of Technology
Department of Industrial Engineering and Management Science

and

Weld–Equip b.v., Helmond

Prototypes as final product

A practical method for profitable systems manufacture

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Institute:
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Masters Thesis report
Gregor W.J.M. Dobbelstein
Eindhoven, June 1995

Preface and acknowledgements

This report presents the results of a Masters Thesis project, carried out at Weld–Equip b.v. in Helmond, The Netherlands. This project is part of the study 'Industrial Engineering and Management Science' at the Eindhoven University of Technology.

It would not have been possible to carry out the project without the cooperation of many different people. Owing to them this graduation project became a valuable experience.

A special vote of appreciation is expressed to the following people:

From the Eindhoven University side, the project has been supervised by ir. L. Monhemius and ir. C.P.M. Govers. Both are thanked for their support, input of professional knowledge, valuable contributions and criticism.

From the Weld–Equip side, the project has been supervised by H.M. Vroomans (major shareholder of Weld–Equip) and ir. C. van Rossum (managing director of Weld–Equip). Both are thanked for supplementing my theoretical knowledge with the necessary practical experience, the amount of time spent on reading and correcting my documents and helping me to execute this project. Especially Mr Vroomans is thanked for his valuable suggestions with regard to this Masters Thesis project, the report's contents and my use of the English language.
I hope the project was as valuable for Weld–Equip, as it was for me.

Apart from the aforementioned persons who were directly related to my project, special thanks are due to the three secretaries Joke, Thea and Leonie for always being there when needing them (both for work as for social purposes).
Finally all Weld–Equip employees are thanked; they always did their utmost in providing information or helping with this project.

In addition, I want to thank all members of my family; you are an important source of inspiration and motivation.

Gregor W.J.M. Dobbelstein
Eindhoven, June 1995

Cooperation has the best chance of being successful when people do not interfere with each other's job and devote one's energy to matters one is optimally master of.

[Bemelmans, 1987]

Abbott's two-dimensional narrator led his readers through a good part of the exercises any citizen of Flatland would go through in perception training, refining the sense of touch and sight so as to come to terms with all reasonable shapes. Similarly, we in three-space learn to interpret the sense data that come to us, gradually coming to the point where we can resolve ambiguities and draw correct interferences from the views presented to us.

introduction [Abbott, 1991]

Abstract

This report is the result of a study, carried out to serve as a Masters Project for graduation at the Eindhoven University of Technology, Graduate School for Industrial Engineering and Management Science. The report's main contents concern an analysis and an improving redefinition and implementation of the engineering process with an engineer–to–order company. The engineering process is broken down into subprocesses; transfer of information within and in between subprocesses is optimized.

Summary

Especially with regard to large projects a huge and complex flow of information is to be controlled. Employees generate information that others will distribute; employees also depend on others' information. Consequently, information control (or in a broader sense 'knowledge management') is essential and necessary. This requires an unambiguous identification of information to be controlled. But also rules relating to those who are responsible for generating, approving and altering information are indispensable.

This report is the result of a research project carried out as the final part of the Masters Program in Industrial Engineering and Management Science at the Eindhoven University of Technology. It has been established at Weld–Equip b.v. in Helmond (The Netherlands), an engineer–to–order company, which means that the engineering process is a part of the primary process of the company. Not only the shipping, the testing, the assembly and the manufacturing but the engineering as well has to take place every new customer order.

Weld–Equip is specialized in delivery of production means (capital goods) for micro–joining of metals. Micro–joining is a process in which, at the location of the joint, the thickness of one of the products to be joined is smaller than 0.5 mm. Major markets are the electronic and fine precision engineering industry. Weld–Equip's turnover in 1994 amounted to approximately 14 million Dutch guilders; they employ approximately 65 people.

The products supplied by Weld–Equip can be divided into two categories, viz.:

- trading products (trade)
- systems

The trade category comprises all products that can be sold directly to the customer. A system can be defined as a solution with value added through R & D and/or Manufacture.

The assignment relates to the system product category and was defined as follows:

"The design of a practical method for profitable systems manufacture, tuned to the actual product market combinations of Weld–Equip"

Consequently, this study addresses a specific section of production situations, the engineer–to–order plants which design and manufacture industrial equipment. This type of production plant is related to engineering and production of complex industrial equipment to fill specific customer orders. These plants operate in a market which can be characterized as being extremely dynamic and erratic. Another characteristic of this market is the large degree of uncertainty which is due to unknown sales volumes and unknown product specifications for future orders. An important aspect is that a significant portion of the products manufactured by these plants must be engineered to customer specifications. This engineering process which precedes the actual manufacture of the product is referred to here as customer order driven engineering or definition phase.

Weld–Equip's system flow in general is analyzed and described. Problems were established with regard to two subjects, viz.:

- **Set of product specifications**: at that moment relatively much effort was needed to obtain *correct* and *complete* system specifications *in time* and *in writing*
- **Communication**: the actual project organisation certainly was far from optimal. Obtaining *consensus* between the parties concerned was a relatively *hard job* at that point in time

These problems occur mainly in the socalled definition phase, which means all stages before the production stage (manufacture). Although these problems also occur in the socalled execution phase, which means all stages from the production stage up to and including the service stage, the problem's impact on the definition phase is the most essential and problematic. That is the reason this definition phase is analyzed and redesigned next.

The analysis and redesign of the structure of the engineering process is based upon the socalled VDI phase model. VDI is short for 'Verein Deutscher Ingenieure' and is in its sort the largest engineering organisation in Western Europe.
The VDI model phases the engineering process (definition phase). At the end of each phase the results reached till then can be compared with the original goals of the project. The engineering process, described in the VDI phase model consist of seven specification sub–processes or steps (figure I).

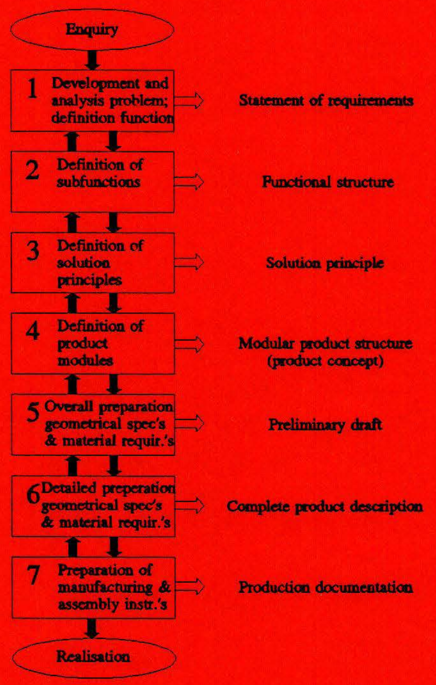

Figure I : Action steps within the VDI phase model

The first engineering step consists of: to define and to analyze the customer's problem and related functional requirements or wishes. This results in a definition of the functional requirements for the custom–built product. The second engineering step involves: to define the functions and subfunctions which must be included in the product. This results in a description of the functional structure of the product. The third engineering step concerns the selection of solution principles. This results in a description of selected solution principles and alternatives which are related to the functional structure of the product. In the fourth engineering step, the subfunctions and associated solution principles are translated into feasible product modules which, together, form the modular structure. A *product module* is a collection of interrelated product components which perform one or more subfunctions. The fifth engineering step provides for a general specification of the geometry and the materials to be used in the most important modules. This results in a preliminary draft of the product in the form of sketches and general specifications. The detailed geometry and materials are defined in the form of technical drawings and bills-of-materials during the sixth engineering step. The technical documentation for the equipments is also prepared. The product description can be considered to be complete after this engineering step. The manufacturing and assembly instructions for all of the product components and subassemblies are developed in the seventh and last engineering step. This activity produces the production documentation needed to manufacture the product.

To overcome the problems described earlier, the engineering process has been analyzed and redesigned. Results of this analysis and redesign are summarized in figure II and will be explained next.

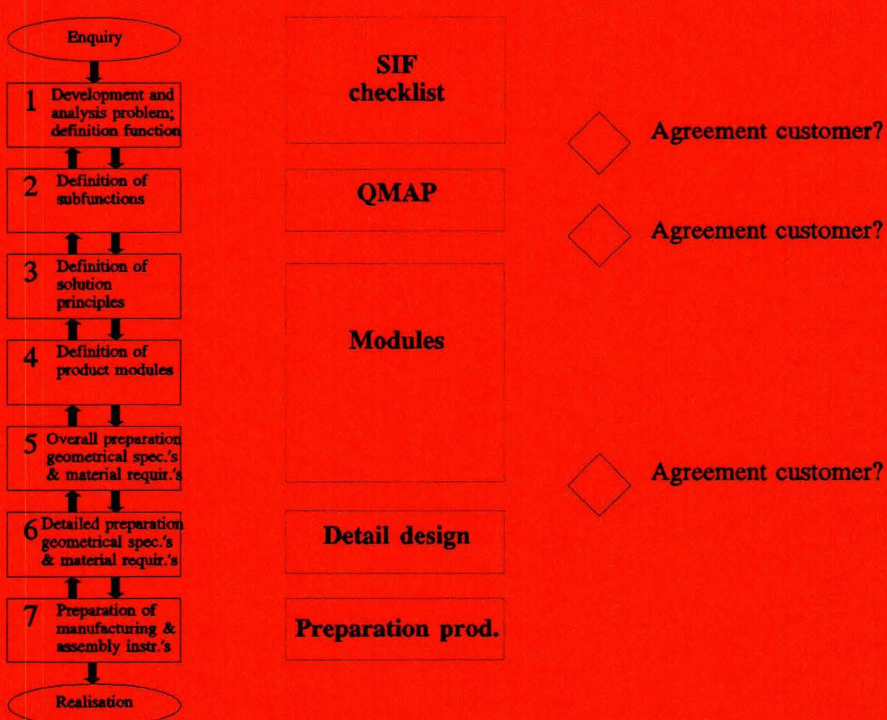

Figure II : Weld-Equip's version of VDI phase model

<u>Step one:</u>

In Weld-Equip step one of the VDI phase model can be filled out optimally by SIF (System Information Form). Since the end of the eighties SIF has been available to Weld-Equip. This form has risen from the conviction that during the first contacts with the customer the important questions are to be asked in a structural manner; the resulting answers are to be written down in a structured way and consequently communicated internally and towards the

customer (means to reach consensus).
However, in reality the form has seldom or never been used. Causes concerned are analyzed by a socalled force field analysis.
Force field analysis' approach is to view change as the result of a struggle between forces that seek to upset the status quo. Driving forces move a situation towards change, restraining forces block that movement.
Thereafter, the form has been renewed and introduced in such a way that it is believed that restraining forces are expected to be reduced or eliminated.

Step two;
With regard to the functional deployment of an enquiry the actual situation fails. The method that structurally can improve this is called QMAP. With regard to the second step of the VDI phase model (definition of subfunctions), the QMAP method optimally fits. Main reason is the fact that QMAP *structurally* applies functional deployment.
QMAP is short for 'Qualitative Models for Analysis of Production systems (Processes)' and it is a method that functionally describes a system, so that

- employees with different backgrounds can communicate about the system concerned in an unambiguous way
- outsiders can be informed about the system and its related performance
- the extreme variation in information can be structured unambiguously and recorded
- specific information is documented for later usage

QMAP results in a functional, schematic description that can serve as basis for further analysis, internal and external communication, and design.
Force field analysis is applied providing an overview of all powers that promote or oppose the use of QMAP. Next QMAP is introduced in such a way that it is believed that restraining forces are expected to be reduced or eliminated.

Step three to and including step five;
With regard to these three steps improvement of modular system manufacture is necessary. Modules should be defined, documented and communicated especially towards the Sales department.
The term module can be defined in many ways. In this report a module is defined as a set of components that fill in one or more subfunctions. The modules philosophy is VDI's step following the functional deployment (QMAP method): the subfunctions defined and documented by the QMAP method are to be translated in pre-defined modules. Consequently, sufficient modules pre-definition is required and is taken care of at Weld-Equip.

Step six and step seven;
Both last steps of the VDI phase model do not require further improvement at Weld-Equip. There are no signs these steps cause considerable problems. Step one to and including step five are basic; of course whenever they go wrong problems will occur in later steps. However when the first five steps have been properly carried out, the chances for problems to occur during the last two steps can be considered as minimal.

Finally this redesign has been implemented and evaluated.

Analysis administrative logistic system

This analysis has no direct relations with the VDI phase model: this project in itself is relatively independent of phasing and redesigning the engineering process. However, the administrative logistic system is part of the presentday method for systems manufacture and improving this system may add to reaching a more profitable systems manufacture.
The actual administrative logistic flow and the problems encountered are described.

Contents

Appendices are in the appendices document

Introduction

Background

In September 1991 the 'Frits Philips Institute for Quality Management' (FPIQM) was formed by Philips Electronics b.v. and the Eindhoven University of Technology. The Institute has the goal to pass concrete methods for continuous quality improvement towards industry. With that goal in mind the Institute combines academic knowledge with practical industrial experience.
Apart from the above-mentioned founders, the Institute has a limited number of partners, currently totalling fifteen organisations. Partners are found in companies that are penetrated by the fact that the quality level within the own organisation and within the supplying organisations is of decisive importance for their own competitive position.

On April 1, 1995 the Institute knew the following partners:
- ACE Ingenieurs & Adviesbureau
- Berenschot b.v.
- Brabantia Holding b.v.
- Cap Volmac Nederland b.v.
- Hogeschool Eindhoven
- Hollandsche Beton Maatschappij b.v.
- Netherlands Car b.v.
- n.v. Koninklijke Nederlandse Vliegtuigfabriek Fokker
- Polydesign b.v.
- Rank Xerox Manufacturing (Nederland) b.v.
- RIVM
- Urenco b.v.
- **Weld-Equip b.v.**

The Institute's research program encompasses three main themes, viz.:
- networks
- control loops
- Quality Function Deployment (QFD)

In pursuance of a presentation on QFD, held by mr Govers in November 1993, contacts were made between the Eindhoven University of Technology and Weld-Equip b.v.. These contacts then resulted in the under-mentioned problem statement and formulation of the assignment.
Weld-Equip is specialized in delivery of production means (capital goods) for micro-joining of metals. Micro-joining is a process in which, at the location of the joint, the thickness of one of the products to be joined is smaller than 0.5 mm. Major markets are the electronic and fine precision engineering industry.
The products supplied by Weld-Equip can be divided into two categories, viz.:
- trading products (trade)
- systems

The trade category comprises all products that can be sold directly to the customer. A system can be defined as a solution with value added through R & D and/or Manufacture.
This study addresses mainly the systems category that is a specific section of production situations: the engineer–to–order plants which design and manufacture industrial equipment.

Problem statement

The core of the problem can be formulated as follows:
"There is a strong suspicion that, when building systems, the phase between problem definition (by the customer) up to and including the guarantee period of the systems delivered by Weld–Equip, can be passed through in a more effective and efficient way. Especially the phase from problem definition up to and including research & development (R & D) appears to be needing closer analysis and improvement".

Formulation of the assignment

The assignment was formulated as follows:

"The design of a practical method for profitable systems manufacture, tuned to the actual product market combinations of Weld–Equip"

Working method and structure of the report

The ultimate way in which the investigation will be executed depends on the chosen investigation method. The use of an investigation method is one of the conditions for a successful investigation result. While working out above–mentioned assignment the following approach to this problem is maintained:
- rough determination of present situation
- determination of ideal situation
- more detailed determination of present situation
- indication of possible improvements
- evaluation of possible improvements and selection resulting in an improvement plan
- implementation chosen improvements
- evaluation and possible action

This approach led to the following structure of this report:

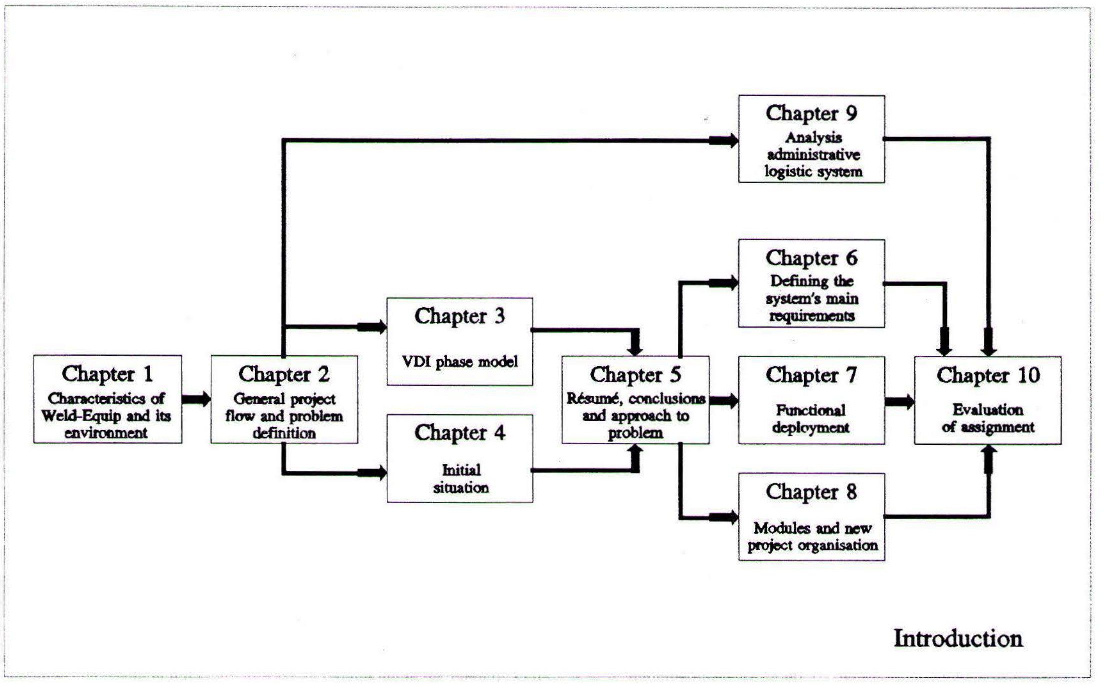

Figure 1 : Structure of the report

This report starts with chapter 1 in which some insight is given in Weld–Equip and its environment.
Chapter 2 provides information about the project flow in general and presents the agreed problem definition, related to the project flow.
Chapter 3 will be about the socalled VDI phase model and Order–independent Specification Levels (OSL's).
In chapter 4 will be investigated how the theoretical background of chapter 3 actually takes place in Weld–Equip practice. Also a short description of the actual project organisation is presented.
The main differences between the chapter 3 and chapter 4 lead to the conclusions described in chapter 5. A description of the approach with regard to managing resistance to change is also included.
Chapter 6 provides information on the topic of defining the a system's main requirements. The socalled SIF will be discussed in this chapter while chapter 7 will be about functional deployment. In this light the socalled QMAP method will be explained and applied.
In chapter 8 Weld–Equip's old and new modules philosophy are presented. Also the new project organisation is described and explained.
Chapter 9 is about the administrative logistic system's analysis while lastly chapter 10 evaluates this study in general; chapter 10 will relate the study's results to the assignment's aim described in this introduction.

Chapter 1 : Weld–Equip and its environment

This chapter contains the following subjects:
- concise description of Weld–Equip
- a short description of its external environment
- recent developments

1.1 : Characteristics of Weld–Equip

1.1.1 : History
In 1957 Weld–Equip was founded and converted into a b.v. in 1961. At that time Weld-Equip b.v.'s core activity was to buy and to sell forge welding equipment and its accessories. Since, Weld–Equip kept pace with continuing technological developments, especially in the field of the micro–joining of metals. Currently, Weld–Equip is active in all four basic micro-joining technologies: welding, soldering, bonding and glueing.
Today Weld–Equip is active not only in wholesale trade, but more and more in engineering and production of customer specific products in this domain.
Because it considers innovation to be of prime importance, Weld–Equip, (ISO 9001 certified), takes an active part in many research projects; some R & D projects are supported by the Dutch government or by European authorities. Also, there is a close collaboration with various European Technical Universities; throughout the world strong links exist with various institutes and experts in the field of micro–joining.
Weld–Equip's turnover in 1994 amounted to approximately 14 million Dutch guilders. At that moment Weld–Equip employed approximately 65 people (including subsidiary companies).

1.1.2 : Policy
Policy and attitude towards the market are focused on guaranteeing the continuity of the company in its entirety; the mission is to obtain a leading position in the market as problem solver in micro–joining of metals. To that end high standing products and services are to be offered.

1.1.3 : Organisational structure
Weld–Equip (Weld–Equip b.v. officially) has three subsidiary companies, viz.:
- Helmond Lastechniek Hellas b.v., Helmond, the Netherlands
- Weld–Equip Sales b.v., Helmond, the Netherlands
- Weld Equip France E.u.r.l., Palaiseau, France

Apart from that, two associated companies exist, viz.:
- Weld–Equip Vertriebs–G.m.b.H., Munich, Germany
- Anglo Weld Equipment Ltd., Cambridge, UK

Practically Helmond Lastechniek Hellas b.v. acts as the production department of Weld-Equip Sales b.v..
Weld Equip France E.u.r.l., Weld–Equip Vertriebs–G.m.b.H. and Anglo Weld Equipment Ltd. represent Weld–Equip b.v. in France, Germany and the UK respectively. Weld–Equip Sales b.v. looks after Weld–Equip's interests in the Benelux and in the remainder of the

world outside the areas covered by the daughter and associated companies.

Appendix 1 presents Weld–Equip's legal structure.
Figure 2 presents Weld–Equip's organisational structure, based on the actual situation.

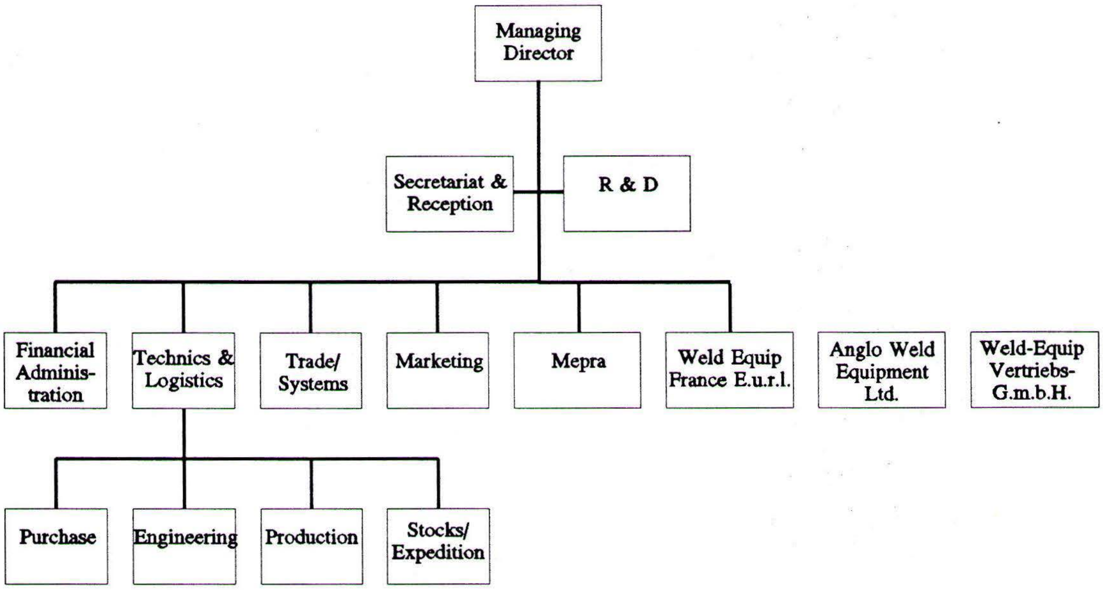

Figure 2 : Organisational structure

'Trade' and 'Systems' are both sales departments. The difference between Trade and Systems is a later subject of elucidation.
Mepra (Mechanisation and production automation) is a department that mainly occupies itself with mechanisation and automation of production environments. Mepra concentrates itself on non–core business. For that reason the Mepra activity is slowly being de–activated.

1.1.4 : Branch

Weld–Equip provides standard joining equipment modules or complete machines (systems) to the electronic and fine mechanical industry, specialized in delivering of problem solving means of production (capital goods) for micro–joining of metals.
Micro–joining has been defined as follows:

> A joining process in which, at the location of the joint, the thickness of one of the products to be joined is smaller than 0.5 mm

1.1.5 : Product mix

Weld–Equip supplies production means which are in the forefront of technology. This applies not only to standard products (trade) from international suppliers, but also to custom made systems, developed, engineered and manufactured in house.

Weld-Equip's most important suppliers are:
- U.M.C. (Unitek Miyachi Corporation), USA
- McGregor Welding Systems, UK
- West.Bond Inc., USA
- E.F.D. International, USA

The application area of micro-joining can be divided into four basic technologies:
- micro-welding
- micro-soldering
- bonding
- micro-glueing

Appendix 2 contains an overview of the micro-joining technology. In each basic technology the one being part of Weld-Equip's present or future technology mix has been indicated.

To summarize: Weld-Equip is specialized in supplying production means for micro-joining of metals (micro-welding, micro-soldering, bonding and micro-glueing), stud welding, micro-dispensing (fluids, glues, soldering paste) and protection products against electrostatic discharge.

The products supplied by Weld-Equip can be divided into two categories, viz.:
- trading products (trade)
- systems

The trade category comprises all products that can be sold directly to the customer.
When the product requires Research & Development (R & D) or Production (or eventually a socalled technical advance study) then this product or order falls under the systems category. Synonyms for 'system' are 'special' or 'project'. Figure 3 roughly illustrates the development stages upon which the difference between trade and systems has been based.

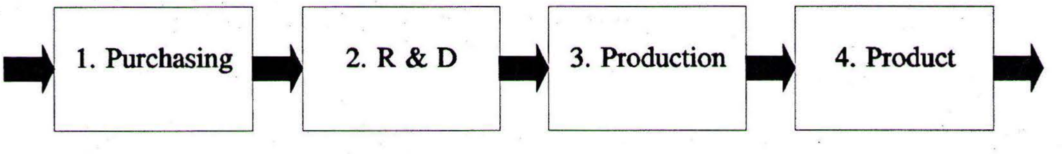

Figure 3 : Development stages

Consequently, a system can be defined as a solution with value added through R & D and/or Production (Manufacture).

1.1.6 : Market

The products chosen here are capital goods which represent major capital investments for industrial customers. The market for these products depends to a considerable extent on the economic climate. This means that sales may vary widely from one period to the next. There is a great deal of competition in terms of price as well as quality. This conclusion is supported by the fact that the number of order quotations is much larger than the number of customer orders actually placed.
Weld–Equip aims at the international market with Europe as the geographical home market. Deliveries to Japan and the U.S. as well as supplies to some other countries outside Europe have taken place in the past and will take place in the future.
Although Weld–Equip does not experience a lot of competition on the aggregate four micro–joining technologies (welding, bonding, soldering and glueing) in the Netherlands, the international market certainly is competitive, especially with regard to the individual basic technologies.

Weld–Equip's goals are:
- to belong to the top 3 in Europe before 1998
- to belong to the top 3 globally before 2000

These positions are to be measured by periodical turnover, profitability, technological innovation, etcetera.
At this moment Weld–Equip should be found just beneath above–mentioned positions.

1.1.7 : Branch developments

The world of micro–joining technologies is highly dynamic. New technologies demand a innovative approach; higher demands are made on reproducibility, quality, reliability, yield, production speed and time to market.
Two important developments are occurring within the branch, namely:
- increasing micro–miniaturization
- increasing need for one–of–a–kind production

Especially the increasing micro–miniaturization requires a growing demand for micro–joining technologies or for component micro–joining equipment. Components continually are getting smaller. As a result of this development higher demands are made on Weld–Equip's products, especially with regard to:
- accuracy
- reproducibility
- reliability

These demands are of importance especially when the following is important:
- high production speed
- great number of process steps

Both branch developments above mentioned result in the fact that the actual importance of Weld–Equip's engineering phase (the main subject of this report) almost certainly will increase in the future.

1.2 : Macro economic influence

Since 1992 the market in general and Weld–Equip experienced the influence of recent recession. This found expression in the necessity of a slight company retrenchment. At this moment signals are observed that perhaps prove that this recession has ended. Signals are for example: greater customers' interest in new plans; growing periodical turnover figures compared with similar periods in the past.
Appendix 3 presents general and company turnover developments that took place during the past five or six years.

Chapter 2 : General project flow and problem definition

This chapter provides information on:
- the course of activities with regard to projects
- the ultimate problem definition and activity priority determination

2.1 : Rough description of project flow

As mentioned earlier, the products supplied by Weld–Equip, can be divided into two categories, viz.:
- trading products (trade)
- systems

When the product requires R & D or Production (or eventually a socalled technical advance study) then this product or order falls under the systems category. Synonyms for 'system' are 'special' or 'project'. Each systems customer order can be viewed as a project with a project network structure consisting of numerous activities to be performed. Normally, a multitude of projects is in production at any given point in time at Weld–Equip.
The process concerning with a customer's interest for a specific project up to and including service with regard to the delivered system, contains thirteen different stages, viz.:
- acquisition
- definition
- technical advance study
- quotation
- order acceptance
- design
- production
- assembly
- test
- pre–acceptance
- delivery (including starting up)
- acceptance
- service

Below, each of these thirteen stages will be described briefly [Weld–Equip b.v., 1993].

2.1.1 : Acquisition stage

In this first stage initial contacts with the potential customer take place. The customer's interest can be made known either to one of Weld–Equip's international offices or to the inside or outside Sales departments of the Dutch headquarters (Weld–Equip Sales b.v.). The manager Sales Systems determines whether the enquiry concerned fits into Weld–Equip's assortment.

2.1.2 : Definition stage

The way in which the specific joining problem is to be defined, is determined in co-operation with the customer. This usually takes place by personal contact between Weld-Equip's Sales department and the customer. During or after this definition dialogue the questionnaire called the 'System Information Form' (SIF) is to be filled out in co-operation with the potential customer.
The Project Co-ordinator (PC) is formally responsible for the fact that every enquiry is to be accompanied by a good and correct specification, set up and modified with the help and co-operation of the customer. Filling out of the System Information Form is obligatory per the ISO 9001-procedures. Whenever the PC and/or the designer thinks the SIF has not been filled out in a satisfactory and sufficient manner, the enquiry concerned should not be dealt with at Weld-Equip.
When a satisfactory filled out SIF has been received, the PC deals with the enquiry. The PC is responsible for getting all information needed within a reasonable term. This information will be the basis for drawing up the quotation. Therefor, the information is passed on to the manager Sales Systems, who is responsible for quotating the customer.

2.1.3 : Technical advance study

Before, during or after the definition stage it can become clear that a detailed inquiry is desirable or necessary. This inquiry usually concerns analysing the possibility of joining two components or materials.
In this case it is the PC's responsibility to decide whether a socalled 'technical advance study' will be carried out. Sometimes, in co-operation with the customer, it is discussed whether a technical advance study may be necessary, how it will be executed and who is going to pay how much of these specific costs.

2.1.4 : Quotation stage

The quotation stage consists of the following activities:
- making an initial sketch (possibly flow chart only)
- description of operation
- determination of (internal) cost price
- determination of sales price and conditions
- making indication with regard to time of delivery
- setting up quotation
- dispatch of quotation

Generally, a quotation consists of:
- a description of the customer's problem and request
- eventually a copy of the technical advance study (if executed)
- an overall drawing and/or photographs to explain offer to customer
- an operational description of the machine/system offered
- the actual quotation (price) and conditions of delivery
- an indication of the term of delivery
- proposed conditions of payment

2.1.5 : Order acceptance

When a quotation turns into an order, there is a milestone: the moment of transfer of the order to the Technics & Logistics department. This is effectuated at the moment the Sales department has confirmed the order to the customer. Afterwards the Sales department and the Technics & Logistics department transfer the order during a meeting and discussion. At this meeting specific information, like drawings, forms, study reports, explanatory documents, samples, etc. are placed at disposal of the persons concerned, so that a start of design can be made.
In co–operation with production management the Project Co–ordinator is to draw up a time plan, based on the agreed delivery date and divided into several subactivities.

2.1.6 : Design stage

While composing an overall drawing, the ultimate system is created. Consultation with the customer is being planned, in co–operation with the Sales department and the designer.
While drawing this first concept, account has been taken of subjects like:

- material choice (sometimes equipment is ordered that has to be installed in socalled 'clean rooms'; or 'ESD' (Electro Static Discharge) equipment is required)
- operational ergonomics
- service friendliness
- safety and environmental requirements
- producibility of the specific parts
- availability of the purchase parts
- costs of the applicable materials and purchase parts
- control software possibilities
- readability of displays, accessibility of the control buttons

While designing production systems, existing modules and parts should be used as much as possible. Also purchase parts should be given preference to parts to be produced.
While the designer is making an overall lay–out, other professionals such as electronic, pneumatic or electrotechnical control specialists occupy themselves with control specifications. Later this information is to be integrated with the designer's ideas about the future system.
As a next step the general drawing is to be detailed; the bill of material is made up. This bill of material and the detailed drawings are the basis for purchase and production.
During weekly projects progress meetings the actual projects and enquiries are discussed. This meeting usually is to be attended by representatives of the Purchase department, Production, Design, Sales and the Project Co–ordinator. At the meeting bottle–necks are put on the order–paper and possibly are resolved. Further planning is discussed and adjusted if necessary. Also alternative actions to be taken are discussed and determined with the intention to ensure a satisfactory project progress.

2.1.7 : Production stage

The bills of material and detailed drawings are being handed over by the Design department to the Production department. An explanation of the drawing(s) is very necessary since critical and non–critical items should be made known as soon as possible.
The purchase parts, as mentioned in the bill of material, are booked at Weld–Equip's supp–

liers by the Purchase department. Production parts are being planned for production by the Production Manager. It is often necessary that specific materials are booked or purchased before production is able to make a start.

2.1.8 : Assembly stage

After all parts have been produced or purchased mechanical assembly can start. During this assembly, special assistance by Design is desirable or sometimes even necessary; changes (due to design changes) are noted on the detailed drawing concerned. When the frame of the system has been built, electrotechnicians normally fit their pants and connect cables correctly (electrical assembly).
After all electrical parts have been correctly connected the control programming and subsequently testing of all movements can be started up. Finally, the electrotechnician also writes the necessary operation and service manual.

2.1.9 : Test stage

System tests usually are carried out by the Production department. It is essential that sufficient samples or products are made available by the customer. If this is not the case then the tests usually are delayed.

2.1.10 : Pre-acceptance stage

As a rule pre-acceptance with the customer present is required. During this pre-acceptance the customer can convince himself that the system or machine fulfils all requirements and specifications, agreed and detailed in earlier stages. Pre-acceptance usually takes place in Helmond. Small modifications can be carried out.

2.1.11 : Delivery stage

When the system has been sent to, received and set up by the customer, starting up can take place, normally on customer's request. During this work often the customer's operating and service employees are trained.
This instruction normally is carried out by Weld-Equip's service engineers.

2.1.12 : Acceptance stage

When the customer evaluated all tests as satisfactory, the system officially changes title. A specific transfer protocol is set up to be signed by both the customer as Weld-Equip. Acceptance normally takes place in customer's premises.

2.1.13 : Service stage

If the specific system does not operate according to the customer's wishes, or during periods of maintenance, service is being carried out at customer's request. Sometimes a service contract has been closed earlier.
In general service is being carried out by Weld-Equip's service engineers.

2.2 : Definition of problem

To get more insight in the assignment as formulated in the previous chapter Introduction and to obtain more insight in the way in which projects are dealt with in reality, the first major activity carried out was interviewing a wide range of Weld–Equip employees. Although the employees interviewed ranged from temporary work men, packing products, to Weld–Equip's managing director, they all have got at least one thing in common: they all occupy themselves with building one–of–a–kind machines (systems) in a project approach.

Summing these interviews it became clear rather quickly that the main problems occurred in the socalled definition phase, which means all stages before the production stage.
Appendix 4 presents fifteen established problems after one month of analysis.

It is a striking fact that a number of problems occurring after the definition phase (the socalled execution phase) stem as consequences of problems occurring in the definition phase.
Summing appendix 4, problems were established with regard to two subjects, viz.:

Set of product specifications

At that moment relatively much effort was needed to obtain **correct** and **complete** system specifications **in time** and **in writing**.

Communication

The actual project organisation certainly was far from optimal. Obtaining **consensus** between the parties concerned was a relatively **hard job** at that point in time.

Figure 4 illustrates the importance of sufficient interdisciplinary communication.

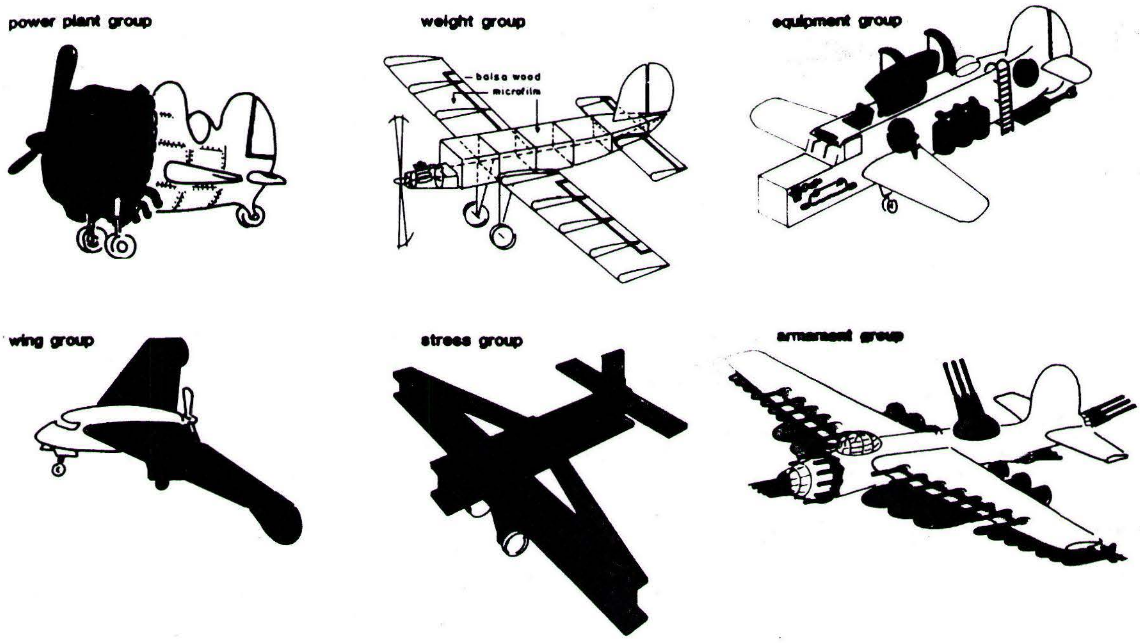

Figure 4 : Consequences of poor communication [Wijnen, 1989]

Poor communication between the six groups will result in 6 totally different airplane designs. However, sufficient communication results in one design, by consensus agreed on by all groups.

One important consequence with regard to systems of the above mentioned problems (set of specifications and communication) is that an extremely low quotation success rate was obtained; only 5% of all quotations turned into firm orders. Another important consequence is that relatively many systems sold resulted in a financial loss.

2.3 : Problems\projects matrix

After these specific problems were established, a difficulty appeared: what to do next? At that moment several alternative solutions could possibly be selected. Consequently clear priorities should be laid down. A tool to establish this is the problems\projects matrix (see figure 5).

Problems encountered \ Projects	x_1	x_2	x_3
y_1		+++	+
y_2	+	+	
y_3	+++	++	+

+	=	the project slightly influences problem concerned in a positive way
++	=	the project influences problem concerned in a positive way
+++	=	the project strongly influences problem concerned in a positive way

Figure 5 : Example problems\projects matrix application

On the basis of filling out of this matrix, an although subjective but certainly unambiguous choice between possible projects could be made. Appendix 5 contains the matrix actually constructed and used. The matrix made it obvious that, at that point in time, SIF (defining the system's main requirements), QMAP (functional deployment) and VDI (terminology to be explained later in this report) had priority over the other possible alternatives.

Next, in chapter 3 the definition phase will be phased according to the socalled VDI phase model. The purpose of this phasing is to get a hold of the specific definition activities.

Chapter 3 : VDI phase model

This chapter provides:

- the socalled VDI phase model
- a description of possible order–independent specification levels

3.1 : Detailing the engineering phase

The core of the definition phase is the argumentation starting with functional specifications leading to (technical and material) shapes. Within the engineering methodology (= the science of methods that get used or possibly can get used for engineering purposes) phasing of the definition phase is seen as an important tool to fill in this definition phase [Roozenburg, 1991].
Phase models divide the definition phase into clusters of activities that mutually are strongly connected. The realization of a cluster (or group of activities) means that a specific stage of the design work has been accomplished. Stages of the design work are for example: the initial concept idea, the functional design or the ultimate design.
The stages concerned generally do not result in alternative designs for one specific problem or enquiry; they provide a framework for detailing one specific design concept. Finishing every separate stage results in an important decision point with regard to the definition phase control aspects; the actual design is being evaluated and possibly action can be taken.

In this report the definition phase is divided into seven phases or steps according to the phase model of the German engineering organisation 'Verein Deutscher Ingenieure' (VDI). Founded in 1856, since VDI has been a general, scientific and politically independent association. VDI is in its sort the largest engineering organisation in Western Europe, having about 125,000 members. In Germany VDI plays a leading role in technology in general.

Figure 6 presents this socalled VDI phase model [VDI 2221, 1986] [Roozenburg, 1991] [Hart, 't, 1992] [Muntslag, 1993], used within the Dutch Stork company nowadays. After completing every single step of the model the design reaches a certain stage of elaboration. This section continues with describing all model steps and further describes the related terminology commonly used.

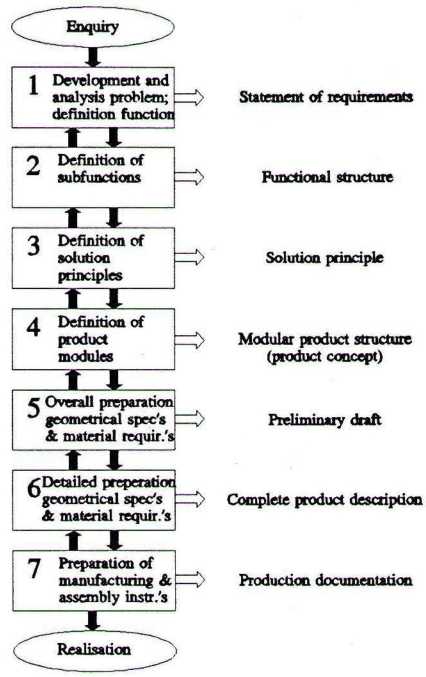

Figure 6 : Action steps within the VDI phase model

The engineering phase can be subdivided into a total of seven engineering steps. The first step is defining and analysing the customer's problem and related functional requirements or wishes. This results in a definition of the main functional requirements for the custom–built product. These requirements are being embodied in the socalled statement of requirements. This statement of requirements serves as input for the second step.

The second engineering step involves defining the functions and subfunctions which must be included in the product. This results in a description of the functional structure of the product. Both the statement of requirements (first step) and the functional structure (second step) specify **WHAT** requirements the system concerned is to be able to attain. This means that it must be clear what input characteristics are to be transformed into what output characteristics. The manner of writing a function usually consists of a substantive noun that is being transformed. This transformation is represented by a verb (for example: *'positioning of wire'*).
The main difference between the first step and the second step is the fact that the second step functionally details the first step. This detailing is continued until the resulted functional specifications easily can be translated into technical (material) specifications. This means that with regard to every single subfunction is determined **HOW** this subfunction technically can be filled in. This is the third step.

Consequently, the third engineering step deals with the development of socalled 'solution principles'. This results in a description of selected solution principles and alternatives which are related to the functional structure of the product.

In the fourth engineering step, the subfunctions and associated solution principles are translated into feasible product modules which, together, form the modular structure. A *product module* is a collection of interrelated product components which perform one or more subfunctions. While working out of the fourth step, the technical concept is determined.

The fifth engineering step provides for a general specification of the geometry and the materials to be used in the most important modules. This results in a preliminary draft of the product in the form of sketches and general specifications.

The detailed geometry and materials are defined in the form of technical drawings and bills of material during the sixth engineering step. The technical documentation for the equipment is also prepared. The product description can be considered to be complete after this engineering step.

The manufacturing and assembly instructions for all of the product components and subassemblies are developed in the seventh and last engineering step. This activity produces the production documentation needed to manufacture the product.

Figure 7 shortly summarizes the used terminology.

Specification process	Input	Output	Output's synonym
Specification of requirements, including main function	The interaction with the potential customer	Sales function (including additional requirements)	General functional specifications
Specification of subfunctions	Sales function (including additional requirements)	Subfunctions	Detailed functional specifications
Specification of technical concept	Subfunctions	Technical concept	General technical specifications
Specification of drawings and partslists	Technical concept	Drawings and partslists	Detailed technical specifications

Figure 7 : Terminology

3.2 : Order-independent Specification Level (OSL)

The specific steps of the VDI phase model can occur customer order independent as well as customer order dependent. The strategically chosen degree of customer order independent engineering can be expressed in terms of Order-independent Specification Level (OSL) [Muntslag, 1993].

Five OSL's can be identified based upon the general description of the engineering process presented above, viz.:

- OSL–1: engineering based on specific technology
- OSL–2: engineering based on pre–defined product families
- OSL–3: engineering based on pre–defined product subfunctions and solution principles
- OSL–4: engineering based on pre–defined product modules
- OSL–5: engineering based on pre–defined finished goods

The OSL represents the lowest level of product description which is still independent of any given customer order. There is, of course, an important relationship between the different OSL's and the engineering process. A certain OSL essentially tells us to what extent the engineering process has already been completed before a given customer order is accepted.

So the OSL has some influence on the way in which the VDI phase model steps are executed; a higher OSL means that more activities of the VDI phase model are carried out independently of the customer order. This approach leads to certain standards for related VDI steps. This means that activities of the VDI phase model can be run over in a relatively faster way.
Also, when only general specifications for a product family have been specified, the product uncertainty is much greater than in a situation in which the product has been fully specified, independently from the customer order.

The degree in which these standards are introduced is a subject of strategic decision making. In specific cases the defined standards will not be applicable and customer order dependent engineering at that specific level will be necessary yet. The degree in which a company is willing to deviate from defined standards is the second strategic decision that needs to be taken in this context.

Chapter 4 : Initial situation

This chapter contains the following subjects:

- the actual way of operation compared to the VDI phase model (chapter 3)
- the Order-independent Specification Level now in operation
- the way in which quotations are transferred
- the former project organization

4.1 : Actual way of operation compared to the VDI phase model

1. Development and analysis of the problem; definition of the main function
The VDI phase model's first step is the development and analysis of the customer's wishes and requirements and the determination of the system's main function. At this moment this step takes place. Actually, when a customer's enquiry is announced it goes without saying that Weld-Equip employees first consider what this potential customer now really is asking for or is needing.
So step one certainly takes place. But the result of the activity should also be registered structurally; it should be documented (recorded, written down), so for example communication about these items could take place more easily. Documenting this information is extremely important in this sort of environments, because during the definition phase and execution phase information about this specific enquiry or order will be carried over to other Weld-Equip employees a couple of times. For example there is the carrying over from the Sales department to the Project Co-ordinator, from the Project Co-ordinator to the Design department, from the Design department to the Production department, etc..
Some years ago the socalled System Information Form (SIF) has been developed. This SIF perfectly fits into the function of the first step of the VDI phase model. Chapter 6 outlines the rise and fall of this form and its present status.
While specifying the customer's wishes and requirements by means of this SIF the system's main function is determined. Main functions that can be filled in are for example: joining, positioning, dispensing, positioning, etc..

Determination of the enquiry's strategic importance, commercial attractiveness and technical risk do not take place in a structural manner and are certainly not registered and sufficiently communicated.

2. Definition of subfunctions and
3. Definition of solution principles
Although with the aid of SIF the system's main function can be determined, this main function is not divided into subfunctions (= answers to the question 'WHAT?'). On the contrary: this determination is omitted and usually solution principles (= answers to the question 'HOW?') are defined and communicated at once. The fact that determination of subfunctions is omitted is caused by some employees' strong conviction about specific solution principles: they rather quickly presume to know the ultimate solution principle.

This manner of problem solving has got one extremely important disadvantage: too soon solutions are considered, and at the same time too little attention is spent on what the customer actually requires and what possible alternatives are available. Also solution principles chosen

are not structurally connected to subfunctions concerned; in other words: which subfunction is executed by which solution principle chosen.
Were subfunctions specified, the logic behind the product concept chosen can be more easily traced. An important additional advantage of a more functionally specified documentation would be the fact that price consequences of specific additional (sub)functions can be translated more easily to the customer.

4. Definition of product modules and
5. General preparation of geometric specifications and material requirements
Next the solution principles resulting from step 3 (the 'vision' of how and by what means a specific problem can be solved) are documented in a general drawing. This drawing is actually composed of the (drawing) modules present at Weld-Equip.
These drawing modules are badly organised and filed. They are filed under 'first drawing date' and the total of drawings is everything but complete and unambiguous. Main goal of these modules is much more to serve as a drawing aid than as a part of company philosophy. By the fact that Weld-Equip's assortment is rather dynamic, these modules can seldom be used in new products or enquiries unless slightly or considerably altered. This alteration seldom occurs.
Consequently the assignment of modules and the general preparation result in a general drawing. Next the customer will be contacted in order to get agreement about this preliminary draft outline. When the customer agrees, next step is detailing this preliminary draft outline.

6. Detailed preparation of geometric specifications and material requirements and
7. Preparation of manufacturing and assembly instructions
The general drawing is detailed in two different views. Next a bill of material of the system concerned is generated, after which another partlist and detailed drawings are generated per item. Next materials and/or purchase parts are ordered and bought. As a final step production is planned. Partlists and drawings, including materials and purchased parts, find their way towards the Production department on the planned production date.

4.2 : Initial Order-independent Specification Level (OSL)

In the recent past Weld-Equip's engineering process was overall characterized by OSL-1. This means engineering based upon a specific technology (see chapter 3 for theoretical background). Weld-Equip's engineering process was best characterized by OSL-1 because it's mission is to obtain a leading position in the market as problem solver in micro-joining of metals. When it comes to OSL-2 (engineering based upon pre-defined product families) there should be at least one or more chosen technologies as well as one or more specific markets (f.e. medical equipment, aviation, etcetera). Although Weld-Equip focused on the metals micro-joining market in general, specific markets were not unambiguously selected. Consequently this last requirement was not the case.

Very recently (November 1994) this strategy was sharpened. Specific product families have been chosen and have been formulated (e.g. heat sealing for the electronic components assembly industry; micro-welding mainly for the tele-communication and automotive industry). These product families will determine Weld-Equip's future assortment.

By this strategy change the OSL in practice changes from OSL–1 to OSL–2. OSL–3 (engineering based upon pre–defined product subfunctions and solution principles) is not yet the case: still some product engineering activities are triggered completely by the customer's order. In the future the OSL will continue to rise, mainly influenced by this strategy.

Figure 8 presents the ideal situation as described by Stork's Central Project called 'Multidisciplinary engineering' [Bosch, 1992]. In this figure the product engineering process (top flow) is independent of every customer request or order. Against that the quotation and order engineering process (bottom flow) use structured product and production information, resulting from the top flow.

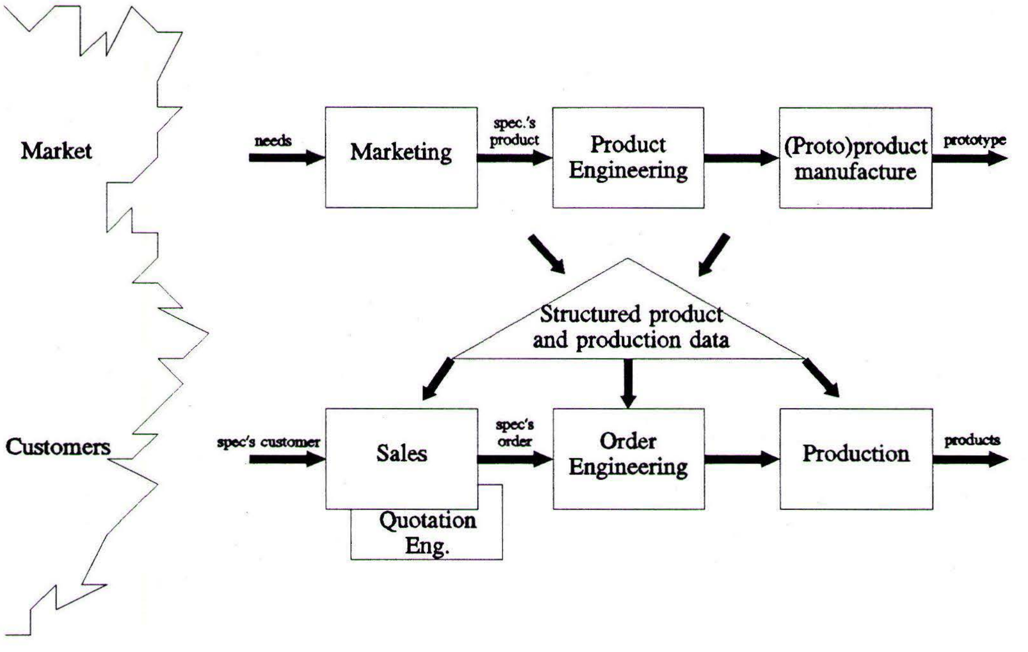

Figure 8 : Reference model of primary process according to [Bosch, 1992]

The product engineering process is triggered by a needs determination by the Marketing department in the customer's market. This needs determination results in certain desired product specifications. These specifications are transformed, designed and built into a prototype concept by the Product Engineering and Production department. Based on Product Engineering and Production data, information is structurally stored for later use during the quotation and order engineering process.

4.3 : Transferring the quotation

A difference can be made between a budget quotation and a fixed price quotation. Offering a budget quotation means that Weld–Equip gives an overall indication of the project price, based on the general essential information regarding the project (goal SIF). In this way one can rather quickly state whether Weld–Equip and its potential customer are talking on the same price level and about the same ultimate system. This is extremely important: when a customer has a price of 25.000 NLG in mind and Weld–Equip thinks that specific problem

only can be solved at a price level of 200.000 NLG, then there is reason to discuss with the customer whether continuation is worthwhile.
This is one of the reasons why it is important that a possible communication failure especially with regard to the price of an enquiry is discovered in a very early stage. A budget quotation is one of possible solutions. This also indicates that whenever SIF is not used (which was the case), transferring a realistic budget quotation will be problematic. The 5% quotation success rate in October 1994 speaks volumes.

Budget quotations are not always presented to the potential customer; this only occurs whenever either the customer or Weld-Equip thinks this is preferable. Usually a budget price indication is preferable in case of rather complex expensive enquiries, although small enquiries sometimes are answered by a budget quotation.
With regard to small, and usually less risky enquiries a budget quotation usually is submitted after determining the solution principles. With regard to more extensive and usually more risky enquiries the budget price indication usually is submitted after the determination of the overall geometry and of the material requirements.

The fixed price quotation is the next step and takes place whenever a previous budget quotation is to be detailed. A subjective interpretation of risk and costs results in the fixed price quotation.
With the previously mentioned strategy change (product families) in mind the submission of a budget quotation in general in a more early stage of the enquiry will be easier if at all necessary. Main reason for this phenomena is, of course, that the creation of product families requires a certain degree of standardization of functions, subfunctions, solution principles and modules. This standardization leads to standard prices, consequently.

4.4 : Project organisation

At this moment the project organization can be characterized as follows:

- there is no person technically responsible for any project
- there is a lack of optimal co-operation between mechanical and electro engineers
- there is no official project team. Discussions usually are informal. Communication is extremely difficult

This results in an invalid project organization that has difficulty to deal with Weld-Equip's dynamic environment. Improvements here are necessary: they will improve success' basic requirement, viz. optimal communication. Following improvements are necessary:

- an official project team is to be formalized; related responsibilities should be stated clearly
- the project team actually is to work as a team

Improvement of the communication without any doubt will be favourable for the success and profitability of the systems manufacture.

Chapter 5 : Résumé, conclusions and approach to problem

This chapter contains the following subjects:
- a short résumé of previous chapter
- conclusions
- a section about resistance to change
- the problem approach

5.1 : Résumé

Especially for larger projects a huge and complex information flow is to be controlled. Employees generate information that others will distribute; employees also depend on others' information. So systematic information control (control of knowledge) is essential and necessary [Wijnen, 1989]. This requires an unambiguous identification of information to be controlled. But also rules relating to who is responsible for generating, approving and altering information are indispensable.

In this light chapter 3 (VDI phase model) presents an optimal framework with regard to the engineering process of a company manufacturing prototype machines. Next the conclusions of chapter 4 are summarized.

5.2 : Conclusions

Chapter 4 justifies the following conclusions with regard to the VDI phase model (see also figure 9):

<u>Step one;</u>
Step one of the VDI phase model can be filled out optimally by SIF. Further analysis of this form and action are described in chapter 6. Next, by means of SIF customer agreement can be obtained.

<u>Step two;</u>
With regard to the functional deployment of the enquiry the actual situation fails. The method that structurally can improve this is called QMAP. Analysis and action with regard to QMAP are presented in chapter 7. Next, by means of the resulting QMAP diagrams customer agreement can be obtained again.

<u>Step three to and including step five;</u>
With regard to these three steps improvement of modular system manufacture is necessary. Modules should be defined, documented and communicated especially towards the Sales department. Chapter 8 deals with this definition and documentation of product modules. Next, by means of the resulting preliminary draft customer agreement can be obtained again.

<u>Step six and step seven;</u>
Both last steps of the VDI phase model do not require further improvement. There are no signs these steps cause considerable problems. Step one up to and including step five are basic; of course whenever they go wrong problems will occur in later steps. However when

the first five steps have been properly carried out, the chances for problems to occur during the last two steps can be considered as minimal.

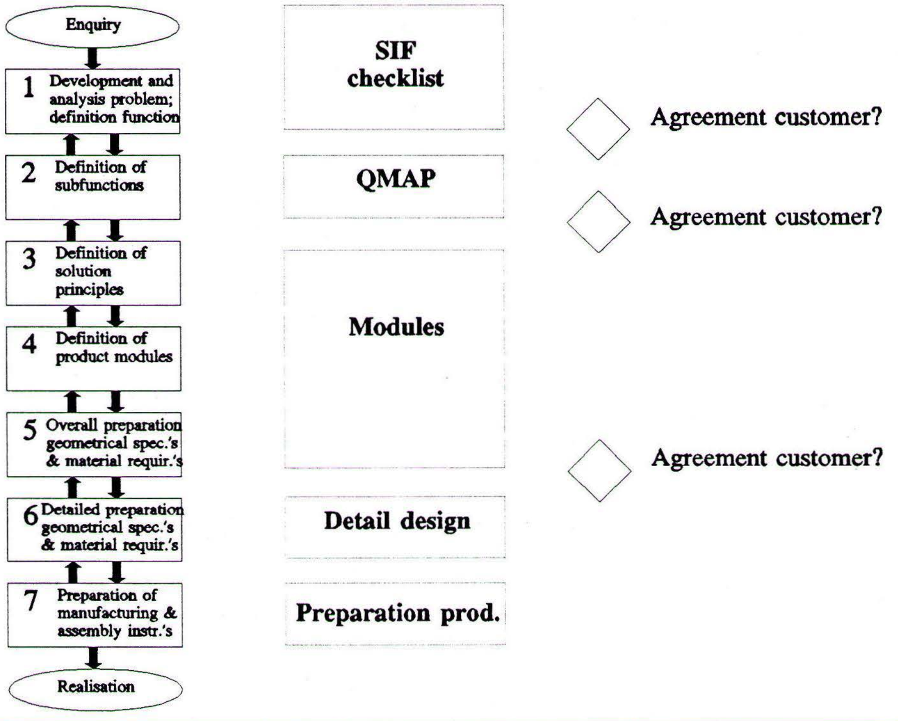

Figure 9 : Weld–Equip's version of VDI phase model

Finally improvements with regard to the project organisation are necessary. A new organization should be defined, agreed upon an implemented. Section 8.2 presents the renewed project organization.
Both the VDI phase model related improvements (SIF, QMAP, modular system manufacture) as well as the project organization alteration have a obviously positive influence on the established problems presented in chapter 2. Both the obtaining of correct, complete system specifications in time and in writing as well as communication in general are improved and possibly solved by sufficient implementation of the presented improvements.

5.3 : Resistance to change

Above mentioned conclusions (SIF, QMAP, modular system manufacture, renewed project organization) make some organisational change necessary and inevitable. Following sections will present the theoretical background of resistance to change.

5.3.1 : Process model

Kurt Lewin [Moorhead, 1989] suggested that efforts to bring about planned change in organisations should approach change as a multistage process. His model of planned change is made up of three steps: unfreezing, change and refreezing (see figure 10).

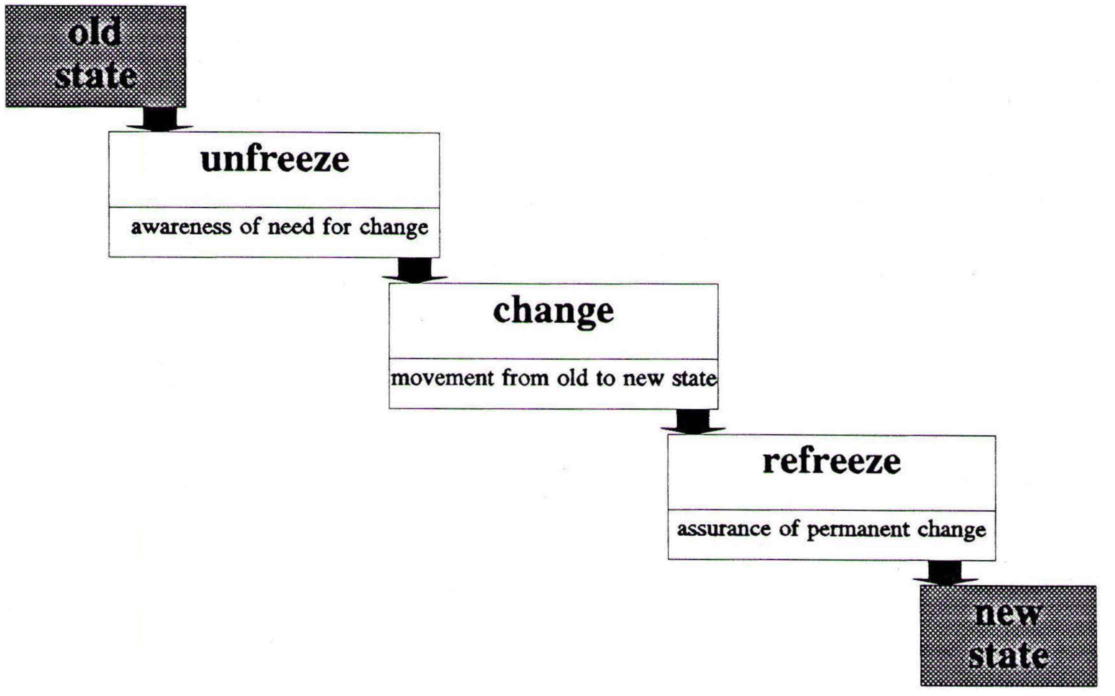

Figure 10 : Kurt Lewin's three-step change process

Unfreezing is the process by which people become aware of the need for change. Change is the movement from an old state to a new one. Refreezing makes new behaviours relatively permanent and resistant to further change.

5.3.2 : Sources of resistance

Just as change is inevitable, so is resistance to change. Paradoxically organisations promote and resist change. A commonly held view is that all resistance to change needs to be overcome, but that need not always be the case [Moorhead, 1989]. Organizational resistance to change needs not be eliminated entirely but can be used and controlled for the benefit of the organisation: resistance to a specific change may cause the organisation to examine more carefully the advantages and disadvantages of the move concerned. Without resistance, the decision may be made before the pros and cons have been explored sufficiently.
Resistance may come from the organisation, from the individual, or both. It is often difficult to determine the ultimate source, however, since organisations are composed of individuals. Various types of organisational and individual sources of resistance are [Moorhead, 1989]:

Organisational sources	Individual sources
Overdetermination, structural inertia (rules)	Habit
Narrow focus of change	Security
Group inertia	Economic factors
Threatened expertise (job redesign)	Fear of the unknown
Threatened power	Lack of awareness
Resource allocation	Social factors (what will others think)

5.3.3 : Resistance management

Resistance can be constructive if it prompts managers to communicate more with employees, re–evaluate the decision to make a change, and perhaps search for new ways to reach the desired goals. A new method may be better than the one originally proposed. More–over, re-evaluating the proposed change in response to employee resistance may be a symbolic act that tells employees management listens to and cares about them. Following six methods are able to deal with resistance to change [Moorhead, 1989]:

- education and communication
- participation and involvement
- facilitation and support
- negotiation and agreement
- manipulation
- coercion ('punishment')

With the last three sections in mind Weld–Equip's process of change has been activated. With the help of interviews, presentations, meetings, discussions and examples (see section 7.3) Weld–Equip employees have been approached. The old state has been unfreezed, changed and refreezed. All six methods to deal with resistance to change (see this section) are applied; one method more frequently than the other.

5.4 : Approach to problem

With regard to the specific inevitable changes to be made, following *practical* approaches, force field analysis (see chapter 6) and PDPC (Process Decision Program Chart) [GOAL-/QPC and Brassard, 1989] are frequently used. Next PDPC will be briefly explained.

PDPC maps out every conceivable event and contingency that can occur when moving from a problem statement to the possible solutions. It in turn identifies feasible countermeasures in response to these problems. This tool is used to plan each possible chain of events that needs to happen when the problem or goal is an unfamiliar one. The underlying principle behind the PDPC is that the path towards virtually any goal is filled with uncertainty and an imperfect environment.
The PDPC anticipates the unexpected and, in a sense, attempts to 'short circuit' the cycle so that the 'check' takes place during a dry–run of the process.
The beauty of the PDPC is that it not only tries to anticipate deviations, but also to develop countermeasures.

Even though the PDPC is a methodical process, it has few guidelines in terms of the process and finished product. Unlike other tools that have a distinctive final appearance, the PDPC could produce two examples that look radically different. Regardless of the specific format created, it must *clearly* indicate expected deviations and possible countermeasures. Following steps are important when applying PDPC:

- determine the basic flow of proposed activities (possible deviations; 'what if's'),
- choose the most workable chart format (graphical; list including steps, problems/contingencies and countermeasures) and
- construct the PDPC using the chosen format.

As mentioned earlier PDPC has been used frequently with regard to the specific projects. Main reason for this is the structured manner in which this method approaches problems. Appendix 6 presents a PDPC real life example with regard to organizing a presentation.

Chapter 6 : Defining the system's main requirements

This chapter contains the following subjects:
- description of the existing SIF and related force field analysis
- from old to new SIF
- presentation of new SIF

6.1 : SIF and force field analysis

Since the end of the eighties SIF has been available to Weld-Equip. This form has risen from the thought that during the first contacts with the customer the right questions are to be asked in a structural manner; the resulting answers are to be written down structurally. In those days general goal of this initiative was to improve communication and transfer of information between the customer and Weld-Equip; and within Weld-Equip.
However, the form is not supposed to contain detailed specifications; it should be seen more as a kind of framework. This general framework will be detailed in a later stage (not with the help of SIF).

SIF contains six sections, which should be filled out with regard to:
- *General information* (bad points old system, requirements of the system, technology group, type of investment, etc.)
- *Operation* (position of operator, system sizes, special safety regulations, etc.)
- *Delivery* (required delivery time, delivery conditions)
- *Instructions* (manual, instructions, etc.)
- *Service* (special wishes with regard to service, service contract)
- *Other particularities* (to be filled out on one's own initiative)

The form is translated from a Dutch version into an English, German and French version. All three international sales offices received copies in their own language.

According to the ISO 9001 procedures SIF should be dealt with as follows:
- It is the Sales department responsibility that SIF is filled out. Weld-Equip employees who can fill out the form are sales engineers, manager Sales Systems and the international sales offices
- SIF is to be carried over from the manager Sales Systems to the Project Co-ordinator. At that moment the enquiry actually is dealt with
- When SIF has not been filled out satisfactorily, according to the Project Co-ordinator and/or the specific designer, then this specific enquiry will not be dealt with

However, reality differs entirely from the situation sketched above.

In reality the form has seldom or never been filled out. During 1993 7% of total annual system enquiries was accompanied with a filled out SIF. During 1994 only 4% of the enquiries was accompanied with a filled out SIF.
Analysing the causes concerned the method called 'force field analysis' was used [GOAL/-QPC, 1988]. Force field analysis' approach is to view change as the result of a struggle between forces that seek to upset the status quo. Driving forces move a situation towards

change, restraining forces block that movement (see figure 11: the driving and restraining forces for change of situation 1 into situation 2).

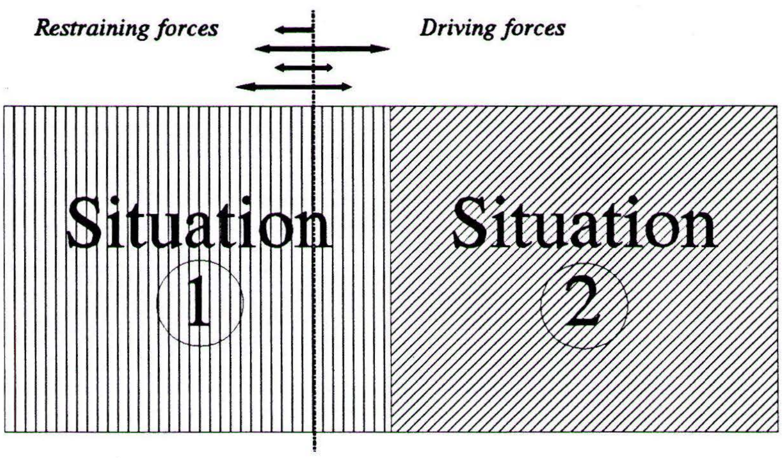

Figure 11 : Force field analysis

When there is no change, the opposing forces are equal to the restraining forces or the restraining forces are too strong to allow movement. If the restraining forces are stronger than the driving forces, then the desired change will not happen. It stands to reason that some change will occur if the driving forces are more powerful than the restraining forces.

Following forces are opposing with regard to SIF:

Driving forces

- Existing SIF is not a poor form. Whenever sufficiently filled out SIF answers essential questions (for example the financial question: 'how much is the customer willing to pay?')
- The form presents a discussion framework. When being used the framework prevents that important items are omitted. In that sense SIF can be used as checklist
- With the help of SIF a sales engineer is better able to structurally help the customer formulate and specify his micro-joining problem. The customer usually has difficulty with this
- It makes a good impression on the customer when the Weld-Equip employee pays really serious attention to the customer's problem by asking essential questions in a structural and quick way
- All customers' enquiries can be delivered in the same format: SIF. Consequently enquiries can be dealt with faster, which means that the total order lead time possibly decreases
- Whenever SIF is being filled out frequently, better and more completely, communication will improve. Less ambiguous and thus improved communication will be possible because it will be clear from the start; and what the customer wants will be written down exactly
- The system's essential information is written down starting from *the most early stages* of the enquiry. Consequently, specific problems are being prevented in time
- Whenever in relation to the actual situation more information is *written down* Weld–

Equip's position in relation to the customer will be stronger. Also these records may perform as a medium to reach consensus with any specific customer. SIF could be sent to the customer to get his approval

Restraining forces:

- SIF has been introduced mainly in connection with Weld-Equip's ISO 9001 certification. At least that is the way most employees live to see SIF. The real purpose has not been made clear sufficiently
- Not every Weld-Equip employee who probably could use SIF, knows SIF's existence
- Every form and particularly SIF is seen as bureaucratic
- Sales engineers are of the opinion that generally speaking they know exactly which questions should be asked in which sequence; in their opinion the form is rather superfluous and in that light time-wasting
- The form contains relatively many questions. Consequently the impression rises that filling out the form is relatively time-consuming
- Filling out SIF can prove that the sales engineer concerned misses some real essential information since as a consequence certain SIF parts have not been filled out. A sales engineer easily can hide this missing information by not using SIF. Instead he hands over information by relatively chaotic visit reports or general ideas
- In specific stages of the request some questions can not be answered or should not be raised. Then a complete filling out of SIF is out of the question. This may lead to not using SIF at all
- A filled out SIF never will be a tight-fitting reflection of the system to be delivered; additional information (extra drawings, specifications) will always be necessary. SIF only contains general information
- Some question's filling out space is too small and some questions are not obvious
- Although filling out SIF is being required by ISO, in reality nobody ultimately takes action whenever SIF is missing in a specific enquiry

One can approach change either from the perspective of strengthening driving forces or from reducing the restraining forces or a combination of these. It has been shown that the most effective tactics is to diminish or eliminate a restraining force. If done honestly, a force field analysis can be a helpful aid to this line of thinking and can be a strategic tool for change.

The decision was taken to renew the SIF and introduce the renewed form in such a way that especially the restraining forces were expected to be diminished or eliminated. This means special attention is to be spent on an introduction of a renewed and altered form that is loud, clear and relatively independent of ISO 9001, clearly indicating the form's function, usefulness and related responsibilities.

6.2 : SIF renewed

With the assistance of the Project Co-ordinator the old SIF has been generally restructured and renewed as a first step. Some questions were removed, others were added and some were improved. In the past the Project Co-ordinator handled the very few filled out SIF's. So he actually knows SIF's status and the information needed with regard to projects in general. Renaming SIF was considered but not carried through in the end because of practical ISO problems.

Next this modified draft SIF was translated into an English version, which was sent to the German office, by far the most important international office for projects. This dispatch was accompanied by a phone call and a personal transfer of the new draft SIF by Weld–Equip's managing director. Purpose of this was to receive any useful addition, removal or advice regarding the form.

The original Dutch version was handed over to all Weld–Equip employees in Helmond who in some way are concerned with SIF: employees that should fill out or should use SIF. The employees concerned were interviewed; they had the opportunity to give their comments with regard to the form. This approach's purpose is to increase participation while decreasing specific restraining forces' weight regarding the use of SIF.

The comments received were seriously considered, resulting in the ultimate modified SIF (version 2). Although the original SIF was available in a Dutch, English, French and German version, the decision was taken that the renewed SIF only would be available in a Dutch and an English version. Main reason was the fact that all Weld–Equip employees are supposed to be able to sufficiently communicate and document in English. Appendix 12 presents the renewed SIF.

The logical next step was the determination of responsibilities: who will have to fill out the form and who will check whether the filling out is sufficient? These responsibilities are formulated in a manual concerning the use of SIF and QMAP (see appendix 12). The manual also includes an example of a sufficiently filled out SIF. The manual is available in both an English version as a Dutch version.

After management approval was obtained the form, including the related manual, has been presented to the employees concerned. This presentation required several meetings and interviews (indoor and outdoor representatives, project team, international offices). See section 7.3 for further details about SIF's implementation.

With regard to renewing an existing form ISO prescribes a number of procedures. These are:

- every employee can suggest changes of (standard) documents
- document changes are recorded in the change form
- the Quality manager determines who should approve changes concerned
- proposed changes are reviewed; after acceptance, these are agreed upon and filed
- the Quality manager only is allowed to change documents; after a change date has been assigned and the document is distributed and filed
- users are informed; old versions are to be taken back by the Quality manager.

In this way the renewed SIF has been formally implemented.

Very recently (June 1995) SIF and related manual are revised slightly; implementation of these latest versions (SIF version 3; manual version 2) is planned in the near future.

Chapter 7 : Functional deployment

This chapter provides information on:
- functional deployment and the QMAP method
- QMAP case studies and applications
- the way of implementation of SIF and QMAP
- the ISO 9001 influence and consequences

7.1 : QMAP

With regard to the second step of the VDI phase model (definition of subfunctions), the socalled QMAP method optimally fits in, it's main reason being the fact that QMAP *structurally* applies functional deployment. Next QMAP will be explained.

QMAP is short for 'Qualitative Models for Analysis of Production systems (Processes)' and it is a method that has been deployed and is being used within the Philips Electronics group of companies. At Philips QMAP's main purpose is to analyze existing production systems (see appendix 22 for Philips CFT visit report). However, for Weld-Equip QMAP is purely an engineering tool.
Weld-Equip's application differs slightly from Philips' application, not only with regard to the application area, but also with regard to the format used..
QMAP is based on a method called 'Structural Analysis and Design Technique' (SADT), a computer software design method. Originally QMAP has been worked out to generate rather detailed qualitative production process descriptions, as mentioned earlier (Philips) [Brondijk, 1993]. These descriptions are the basis of further analysis and improvement.

In general QMAP's main purpose is to functionally describe the system (or machine), so that:
- employees with different backgrounds can communicate about the system concerned in an unambiguous way
- outsiders can be informed about the system and its related performance
- the extreme variation in information can be structured unambiguously and recorded
- specific information is documented for later usage

A good qualitative description and discussion of the technical subprocesses within a new system gives insight in possible (future) problems. Also it may give insight in possible alternative designs.

QMAP results in a functional, schematic system description that can serve as basis for further analysis and design. That is why the design quality is directly related to the quality of the functional description.

7.1.1 : Black box approach

An important characteristic of the QMAP method is the fact that QMAP describes the system concerned on different detail levels; a start is made with the most general level (system's main function) after which detailing takes place (functional deployment).
The description of the system starts with formulating the main function of the system con–

cerned. The system is considered to be as a socalled black box (black box approach); whatever happens within this box is not of importance at that moment.
Figure 12 presents a practical example of QMAP's A–0 diagram; the A–0 diagram presents the systems main function (in this case 'the covering of glass objects with paint resulting in coloured glass objects').

In general the QMAP diagram is being composed of the QMAP circle and of arrows. The circle is being filled out by a verb (the TRANSFORMATION) which optimally describes the production system's main function.

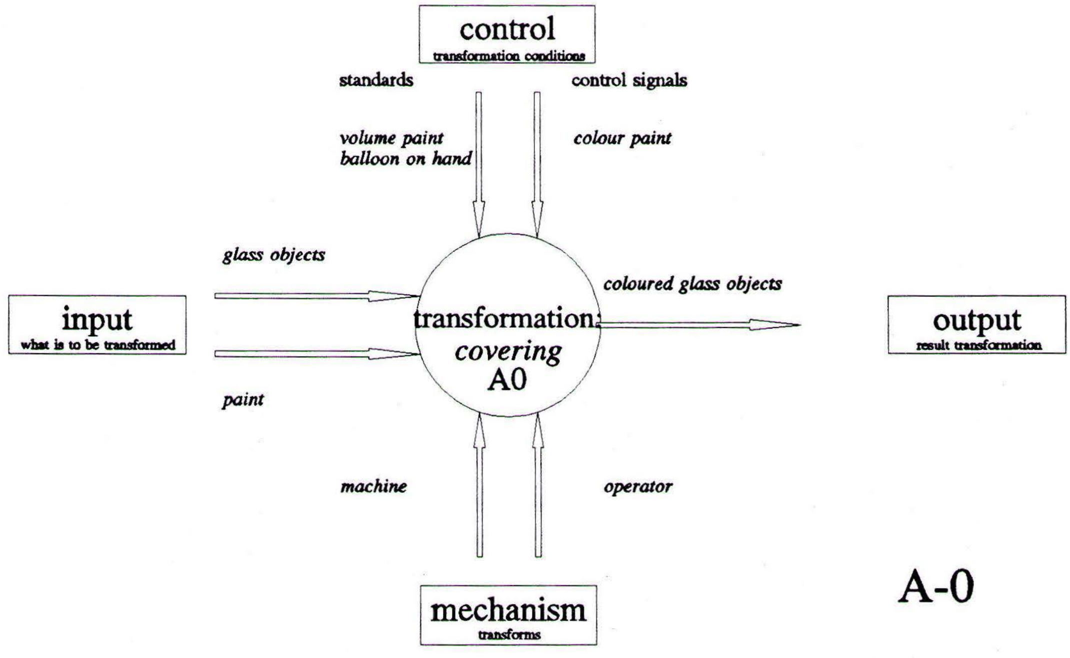

Figure 12 : QMAP diagram

Normally, functions describe dynamic situations; this means that the system has got an INPUT and an OUTPUT; the INPUT is transformed into the OUTPUT. INPUT and OUTPUT are defined as follows:
INPUT stands for what is to be transformed.
OUTPUT stands for the desired process result.
Both INPUT as OUTPUT usually are being described by means of a noun plus eventually adjectives. The combination of the INPUT, OUTPUT and TRANSFORMATION description should optimally describe the function concerned.
Next step is the determination of the socalled MECHANISM.
MECHANISM stands for the means of TRANSFORMATION to turn INPUT into OUTPUT.
MECHANISMS also usually are described as a noun.
Next TRANSFORMATION conditions are described;
CONTROL stands for the logic to transform INPUT into OUTPUT.
The CONTROL part can be divided into two categories, viz. control signals and standards.

Control signals
Control signals come from outside the system (external). For example: the production manager can instruct to change production of blue glass objects to production of red glass objects.

Standards
The above mentioned external signals are not sufficient to attain the OUTPUT needed. Within the system conditions have to be determined with regard to the INPUT, MECHANISM and OUTPUT. These conditions are called standards. For example: whenever the paint temperature is below a certain level, a specific action should be taken.

In QMAP the CONTROL items usually are described by nouns, indicating what has to be controlled.
So per block (figure 12; INPUT, OUTPUT, MECHANISM, CONTROL) important information or requirements have to be described. The information on this level (A–0 level) refers to the system as a whole (so not to specific subfunctions).

7.1.2 : Detail levels

While applying QMAP the build–up of QMAP diagrams is combined with a system approach; the overall system is subdivided into system parts with their own boundaries. One starts at the highest possible level: the total system. This level (A–0 level) describes the total system; on this level there is only one transformation. Next step is detailing the above mentioned A–0 level. This practically means that necessary subfunctions are defined and interrelated.
This detailing activity should stop when the resulting subfunctions easily can be translated into technical language (e.g. modules, things). Figure 13 illustrates the socalled A0 level. The example's main function 'covering' is being deployed in the subfunctions 'mixing', 'dispensing', 'positioning of glass objects', 'painting' and 'removing'.

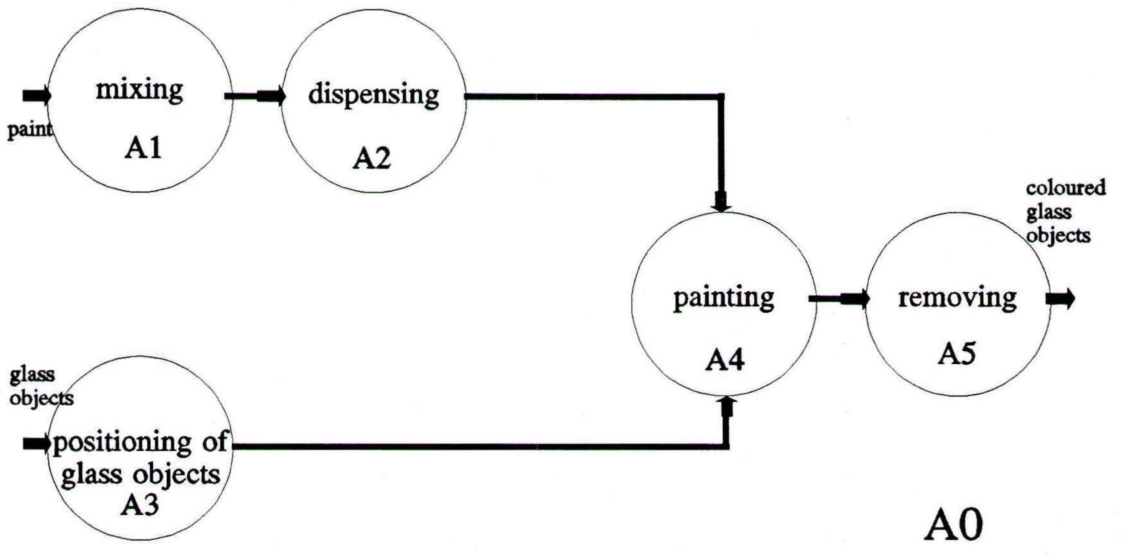

Figure 13 : Functional deployment

So when the system has been detailed sufficiently, the structure and related coherence has been determined. Per final subfunction a QMAP diagram will be laid-out, containing detailed information and requirements that are essential to the system. For this detailing purpose figure 12's format is used. With regard to the example "covering glass objects" five QMAPs are to be made (A1 up to and including A5), each one dealing with one subfunction.

When applying the QMAP method, following rules are to be taken into consideration:

- diagrams to be constructed, start on the highest system level, stepping down to detailing subfunctions
- of all lower level subfunctions a QMAP diagram is to be made
- all QMAP diagrams are to be mutually consistent

7.1.3 : Interdisciplinary co–operation

A model constructed and filled out by only one person is always one–sided; in such a model the vision and thoughts of only one person with regard to the system are documented and presented. This one–sidedness can be prevented by constructing and filling out that model in multi–disciplinary groups.

The QMAP method is very suitable for interdisciplinary co–operation. This is because the model describes the system functionally, which means that every specialist has to translate his information in a terminology that everybody understands. QMAP forces the process to be truly mechatronic.

The QMAP method unambiguously structures the information coming from different disciplines; this is possible because information is documented using a functional performance terminology or language.

Based on the presented problems encountered and on the characteristics and advantages of the QMAP method, the decision is made apply the QMAP method in the future as standard method to functionally deploy prototyping enquiries: QMAP is to be and will be used as engineering tool for the proto product manufacture (see figure 8).

7.1.4 : Force field analysis

Of course, force field analysis also is applicable to QMAP; which powers promote the use of QMAP (driving forces) en which powers oppose the use of QMAP (restraining forces);

Driving forces:

- QMAP is simple and unambiguous
- QMAP is flexible: QMAP diagrams are readable by all company disciplines and all kind of employees; knowledge of a specific technical language is not required. So use in multidisciplinary groups is possible. QMAP acts as communication aid
- QMAP describes measurable performances
- QMAP is easy to use
- QMAP is easy to learn
- QMAP is suitable for both overall as well as detailed system descriptions
- QMAP has an important characteristic: it interrelates above mentioned general and detailed system descriptions
- QMAP enables its users to become aware relatively quickly whether specific information is missing or whether requirements are contradictory. The reason for this phenomena: QMAP structurally approaches problems

QMAP has the following additional driving forces specially for Weld-Equip:

- QMAP is the optimal tool with regard to the deployment of SIF's main function. The formulated main function is divided structurally into interrelated subfunctions.
- QMAP is very suitable for prototype production environments: the method is so flexible that it can describe any system requested in a structural manner, no matter how complex. The effort needed is relatively small compared to application of e.g. QFD
- QMAP being used as a rule, Weld-Equip's more or less chaotic systems documentation will be simplified; communication will be less problematic and error chances will be reduced
- QMAP increases structured documentation and formalisation what will lead to an improved knowledge management within Weld-Equip
- QMAP requires information to be structurally *recorded*. This will strengthen Weld-Equip's position related to the customer. Also these records can function as a medium to reach consensus with specific customer requirements. QMAP diagrams could be sent to the customer to get his approval
- QMAP diagrams can serve as a kind of promotion or sales tool. Specific subfunctions have specific prices; financial consequences of specific additionally requested subfunctions easily can be made clear. Consequently, QMAP improves Weld-Equip's price performance ratio justification
- QMAP forces parties concerned (including the customer) not only to think in functions and modules, but also to document (write down) and communicate specifications in functions and modules

Restraining forces:

- constructing QMAP diagrams appears to be difficult and time-consuming. However, the more diagrams one has constructed, the less time is needed to construct a single diagram (learning curve).
- it is possible that some employees do not see QMAP's benefits immediately. They may not clearly notice occurring problems and may have no idea how QMAP may improve the actual situation
- every change will cause some resistance (see section 5.3). So will QMAP because this method is totally new and will change the actual way of working
- some training will be necessary

As mentioned in chapter 6, one can approach change either from the perspective of streng-thening driving forces or reducing the restraining forces. It has been shown that the most effective tactics is to diminish or eliminate a restraining force. So while discussing, applying and implementing QMAP the reduction or elimination of the restraining forces has been emphasized. This means that demonstrating and explaining the method is essential for successful implementation and application.

7.2 : QMAP case studies and real life application

Next a short survey will be presented of QMAP applications. Following sections will contain several case studies (section 7.2.1 up to and including section 7.2.3) and two real life appli-cation (section 7.2.4 and 7.2.5). The case studies are based on enquiries or orders that was dealt with in the past. The real life QMAP applications are actually constructed and used in practice.

7.2.1 : Tele Quarz Group

The Tele Quarz Group is an Austrian company that manufactures electronic components. The Tele Quarz Group enquired and ordered a system for welding wire on crystals. However, all kinds of problems occurred during engineering, production, service and starting up, mostly based on the interpretation of the set of specifications and based on internal and external communication problems in general.
The purpose of applying QMAP afterwards was to investigate whether QMAP could have prevented some or all problems. The conclusion of the investigation was that the actual situation certainly would have been improved had QMAP been applied structurally and inter-disciplinary (including the customer).
See appendix 7 for the related QMAP diagrams. Within Weld-Equip this QMAP application is used as case example during discussions, presentations and meetings. An important reason is the fact that this application is an excellent example of how things can (and will) go wrong (Murphy's law) when problems are not approached structurally and interdisciplinary.

7.2.2 : CEM; Robert Bosch Elektronik G.m.b.H.

Constructing the CEM (which means 'Centrum für Mikroverbindungstechnik in der Elek-tronik Forschung und Entwicklung G.m.b.H.') and the Robert Bosch Elektronik G.m.b.H. QMAP diagrams, both based on different welding system enquiries, appeared to be imposs-ible. This impossibility of constructing a QMAP was caused by a total lack of essential information.

However, this result proved that QMAP structurally approaches the customer's problem and whenever essential information is missing, this (if QMAP is being applied well) will be discovered. Next, action can be taken to obtain the missing information.

7.2.3 : Rostock Elektronik Produktion G.m.b.H.; Söhnle-Waagen G.m.b.H.

Although the Rostock Elektronik Produktion G.m.b.H. (heat sealing) and the Söhnle-Waagen G.m.b.H. (welding) QMAP diagrams actually have been constructed, this does not mean that the resulting diagrams were satisfying; the QMAP diagrams proved that information lacked concerning specific subfunctions.
See appendix 8 and 9 for the resulting QMAP applications.

7.2.4 : Fin Inc.

Although above mentioned case studies all are based upon past enquiries and orders, the Fin Inc. application of QMAP is used in reality.
The name 'Fin Inc.' is fictitious, because a non-disclosure agreement was signed by Weld-Equip. The company concerned is a mobile phones manufacturing department of an international enterprise. The actual enquiry concerns an inline encapsulation system (dispensing) for wire bonded IC's.
QMAP is applied, based on the information sent by the customer. Constructing the QMAP diagrams resulted in some essential questions which were communicated towards the customer. Next these QMAP's were discussed in an interdisciplinary group (an early version of the future project team), resulting in revised QMAP diagrams. These diagrams were sent to Weld-Equip's dispensing partner LCC (Liquid Control Corp., USA) and to the customer, intending to reach a certain degree of consensus and approval.
Although reactions in general concerning constructed QMAP diagrams being very positive, the order was not given to Weld-Equip. Main reason was Weld-Equip's relatively long reaction time and the liberal delivery time.
See appendix 10 for the resulting QMAP diagrams.

7.2.5 : Biotronik Corporation

Lastly the QMAP method is applied to a welding system enquiry and order by the Biotronik Corporation. Biotronik is a German manufacturer of cardiac pacemakers and the company is seated in Berlin.
Although this project already was an order, it was decided to apply the QMAP method. Main reason was the fact that this order is a typical proto product. Also this order is that big (in financial terms) and complex that this QMAP test application was initiated. Although the enquiry already was an order, internal communication was not initiated at that moment; consequently, there was an opportunity for the application of QMAP.
The QMAP diagrams were constructed in close collaboration with the Project Co-ordinator, based on the official and already agreed on set of requirements (the socalled Pflichtenheft).
See appendix 11 for the resulting QMAP diagrams.
After constructing the QMAP diagrams, some essential requirements were discussed and stated more clearly. Next the QMAP diagrams were used as interdisciplinary communication tool.
Reactions with regard to the QMAP application were very positive. Although applied too late, the QMAP method structurally analyzed. checked and arranged (in this case) already

present information. However, when applied correctly and sufficiently, QMAP has the power to improve the systems manufacture considerably.

7.3 : Implementation SIF and QMAP; resistance management

Next a survey will be presented of the actions taken to manage the existing resistance. See chapter 5 for the more theoretical background.

7.3.1 : Interviews and involving

Interviewing has been a major means to manage resistance. During the interview one gives the interviewed person the opportunity to participate in solving the occurring problems. In this way the employee gets the just feeling that his opinion is of essential importance and his suggestions about possible improvements or about already proposed improvements is a necessity for future successful change.
Apart from interviews, distant employees (international offices, especially Germany) frequently were approached by mail (QMAP diagrams), fax and telephone.

7.3.2 : Manual

To accompany SIF and QMAP, a descriptive manual has been made. Main purpose of this manual is to describe both the SIF and the QMAP method and to assign related responsibilities. Assigned responsibilities can be summarized as follows:
The Sales department is responsible for sufficient use of SIF. Application of QMAP is the responsibility of the new project team. See section 8.2 for a short summary of the new project organisation's characteristics.
The manual has been provided to all Weld-Equip employees who in future will get in touch with SIF or QMAP. Also a QMAP standard was included (see appendix 13)
See appendix 12 for both the English and the Dutch manual.

7.3.3 : Meetings

Meetings (and also presentations) were organized to introduce and implement the renewed SIF and to elucidate the QMAP method. Both meetings and presentations (see next section) provide the opportunity to provoke the necessary discussion. Two main differences between a meeting and a presentation are the style of informing the employees and the actual number of auditors.
Three milestone meetings were organized. The first two meetings both took place on March 20, 1995. The first meeting concerned the inside and outside Systems Sales department; the second meeting concerned the inside and outside Trade department. The Trade department was involved because sometimes this department is also confronted with prototyping enquiries (especially with regard to dispensing).
The third meeting was organised on March 29 and 30, 1995 in Germany. This meeting involved the manager of Weld-Equip Vertriebs-G.m.b.H., the manager Sales Systems and the writer. Main purposes of this meeting were to exchange ideas about possible improvements with regard to systems in general and to get an agreement on the future use of SIF. The meeting was combined with a customer visit (VDO). See appendix 22 for more details and discussion results.

7.3.4 : Presentations

Totally two milestone presentations were organized. These presentations made it possible in a relatively large group to discuss and agree on the use of SIF and the QMAP method. Following presentations were organized:

- February 8, 1995; internal presentation
  See appendix 14 and 22 for the overheads used and the feed–back reports.
- April 11, 1995; international managers meeting presentation
  See appendix 15 and 22 for the overheads used and the feed–back reports.

7.3.5 : QMAP as a sales tool

Not only the project team is directly confronted with the QMAP method. Also the Sales department got acquainted with QMAP. Not only by means of presentations, meetings, manuals, etc., but also by QMAP diagrams being part of the future sales tool of the defined product families. This future sales tool shortly will be explained.
For every product family the following documentation (sales tool) will be available to the sales engineers:

- a general brochure about the product family concerned
- pictures of already made and/or delivered systems (with regard to this specific product family)
- the QMAP application
- overall drawings

The heat sealing product family is the first product family to be worked out. For information about the heat sealing process see section 8.1.3. For the heat sealing QMAP application see appendix 16.
Although in this case QMAP is not used purely as an engineering tool (product families implicate relatively standard products), this application gives especially the sales engineers the opportunity to get used to the QMAP format and approach.

7.4 : ISO influence and consequences

In relation with ISO, every constructed QMAP should contain at least follow information:

- the customer name
- the project number
- the construction date
- the version number
- the constructor

This information is required because every document should clearly indicate which project it is part of. Whenever information is changing, a new QMAP can be made; the old ones, including copies of the old ones, should be removed.
The originals of SIF and QMAP should be filed in the project file, controlled by the Project Co–ordinator.

Chapter 8 : Modules and new project organisation

This chapter contains the following subjects:
- description of Weld-Equip's actual and future modules philosophy
- the new project organisation

All items discussed in this chapter are not directly part of this Masters project. However, their relationship with the QMAP method and the VDI phase model is considerable: the modules philosophy is VDI's step following the functional deployment (QMAP method). Improvement of the project organisation is essential for successful QMAP application.

8.1 : Modules

As mentioned in chapter 5, the subfunctions defined and documented by the QMAP method are to be translated in pre-defined modules. Consequently, sufficient pre-definition of modules is required. The term 'module' can be defined in many ways. In this report a module is defined as a set of components that fulfil one or more subfunctions.

8.1.1 : Modules actually defined

As described in chapter 4 the modules philosophy presently used at Weld-Equip can be used only as a kind of drawing aid. Modules present range from drawings of total systems to drawings of all kinds of screws and nuts: an integral one level module philosophy is missing. Consequently, the main purpose of the actual modules application is rather limited: modules are only applied to reduce time spent on drawing the system or system components.

8.1.2 : Future modules application

As part of the product families strategy recently introduced (see chapter 4) the definition, introduction and application of a companywide module philosophy has become indispensable. In the near future the Sales department will be able to quickly compose a system out of pre-defined modules especially with regard to product families enquiries; consequently, this department will be able to rather quickly relate such an enquiry to a realistic price.
Since different product families were defined, the definition and introduction of the actual modules was initiated for the product family 'heat sealing'. Next, the heat sealing process will be explained and the resulting modules will be presented.

8.1.3 : Heat sealing process

Heat sealing is a microjoining process frequently used to join Printed Circuit Boards (PCB's), Anisotropic Conductive Films (ACF's), Liquid Crystal Displays (LCD's) and Heat Seal Connectors (HSC's) (see figure 14) [Weld-Equip b.v., 1994].

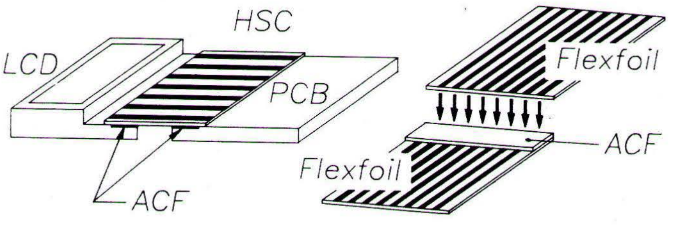

Figure 14 : Applications for heat sealing [Weld–Equip, 1994]

ACF filled with small particles with a conductive coating take care of the electrical contact between the electrical conductive areas on a display, PCB and flexible foil with conductive tracks (HSC), if properly applied.
In order to bring the conductive particles, spread at random in the adhesive, in continuous contact with both electrical contact areas, the adhesive must be heated under pressure. The deformed particles finally establish the electrical contact between the parts to be connected (see figure 15)

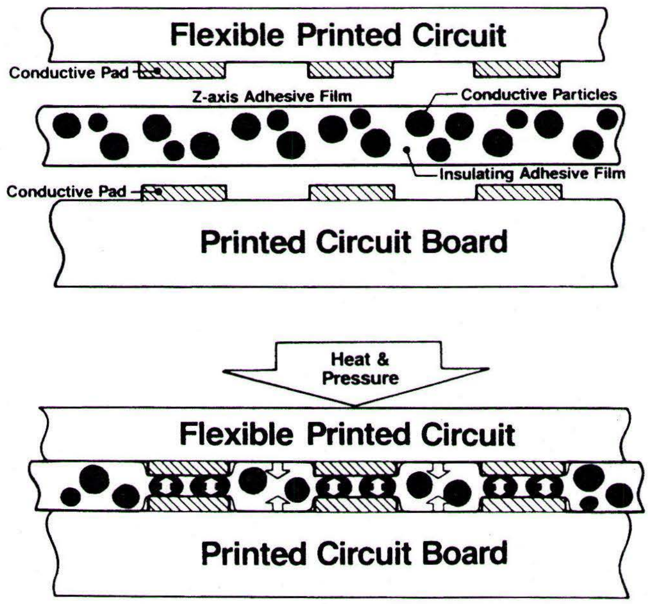

Figure 15 : Principle of connections [Weld–Equip, 1994]

The combined and controlled process of heating and pressing together is called heat sealing. Appendix 17 presents a draft version of the heat sealing module philosophy, worked out by Weld–Equip. This list is not yet complete and determination of related prices is still to be carried out.

Some heat seal modules can be applied also in or for other product families (e.g. product handling).

8.2 : New project organisation

Based upon the conclusion presented in section 4.4, recently specific project organisation changes are implemented. Next these changes will be summarized.

Following changes have been implemented:

- a project team is created consisting of six permanent members
- every single project is led by one of the members (Project Leader). This Project Leader will be assigned to the project concerned; he is supposed to monitor the project's progress. Obstructions or bottle-necks are to be reported and eliminated
- the Project Co-ordinator is part of the team. He determines which team members will play an essential role with regard to the specific project. The PC will still be responsible for adequate communication between the Sales department and the project team
- the members of the project team are hierarchically on the same level and are trained to work as a team
- this project team will be responsible for sufficient future QMAP application

Chapter 9 : Analysis administrative logistic system

This chapter will shortly describe the approach of the administrative logistic system's analysis and will refer to the appendices document for the analysis' results.

It should be mentioned that this analysis is not directly related to the VDI phase model: this study is relatively independent of phasing and redesigning the engineering process. However, the administrative logistic system is part of the present method for systems manufacture; improving this system may add to reach a more profitable systems manufacture.

9.1 : Approach

Analysis of the administrative logistic system means basically analysing which activities are performed, starting with an enquiry from the customer to and including the debtors account management in general. In addition, these activities not only refer to administrative procedures; related logistic aspects are also to be taken into account.

Initially, the analysis was initiated with the intention

- to chart the actual way of working with regard to administrative logistic procedures
- to record the most urgent problems and bottlenecks
- to present possible improvements
- to choose and implement selected improvements

A flow chart description of the actual way of working is presented in appendix 18. The flow chart method is selected based on its power to present complex situations rather clearly. Appendix 18 is based on a number of interviews and observations. It can be concluded from the analysis results presented in appendix 18 that the actual (use of the) administrative logistic system is far from being optimal. The system is characterized by a long, winding flow instead of a short and straight line. Moreover, one should strive for a flow that is as straight and short as possible.

Consequently, problem descriptions, based on the current administrative logistic system are presented in appendix 19. It should be mentioned that the actual situation and resulting problem formulations are not fully analyzed and for that reason rather superficial. With regard to specific subjects more detailed and more founded analysis may be required. Consequently, improvement formulation and implementation is to be planned in the near future.

9.2 : Future action

Summarizing previous section: more detailed analysis, redesign and implementation is required. At the moment of the presentation of this report, future actions are drawn up and planned. The degree of participation of the writer is subject of negotiation.

Chapter 10 : Evaluation of assignment

In this chapter the conclusions of this study will be presented with reference to the assignment's aim as described in the introduction of this report

Customer order driven engineering can be explained based upon the following characteristics:

- *Product and process uncertainty*
  One of the important characteristics of engineer-to-order production is the fact that products are produced which are custom-built; therefor these are unique. The details of each product to be produced are unknown when the order is accepted (product uncertainty). As a result, there is no (detailed) knowledge of the capacity requirements (process uncertainty). This means that, especially at the start of the customer order driven engineering activity, assumptions are to be made and decisions are to be taken under conditions with a certain degree of both product and process uncertainty.
- *Changes and disturbances*
  Various changes and disturbances can occur while the customer order driven engineering activities are being performed. A good example of an (external) change would be the recognition of new customer requirements with respect to the ordered product. Such changes may have significant implications on the time-related and/or cost aspects of the current order as well as for other customer orders being produced and for future customer orders
- *Iterative nature*
  The iterative nature of customer order driven engineering activities is to be be seen as an important characteristic. After the completion of a given task, it is generally possible and often necessary for a number of reasons to redo a previous task. This kind of loop in executing a given activity means that certain tasks are repeated and the previous results of a repeated task then need to be revised.

The three characteristics of a customer order driven engineering activity as described above for an engineer-to-order production situation are, of course, not independent of each other. The dominating product and process uncertainties may be seen as main reasons for internal and external changes. In addition, the iterative nature of customer order driven engineering activities is caused largely by the changes and disturbances which occur during this phase. A previously executed series of tasks may need to be repeated completely or partially whenever a change is introduced.

In this context it is essential that the huge and complex information flow is to be controlled. This requires an unambiguous identification of information to be controlled. But also rules are indispensable relating to important items like who is responsible for generating, approving and altering information. Sufficient information control will positively influence or solve problems stated in chapter 2, viz. with regard to:

- **Set of specifications**: relatively much effort was needed to obtain *correct* and *complete* system specifications *in time* and *in writing*
- **Communication**: the actual project organisation certainly is far from optimal. Obtaining *consensus* between the parties concerned was a relatively *hard job* at that moment

To improve or to solve this, the definition phase (the engineering process) is analyzed and redesigned. Next this redesign is implemented.
This analysis, redesign and implementation are based on the VDI phase model.

The contribution of the VDI phase model to the engineering process of Weld–Equip can be one of great value. The VDI phase model presents an optimal framework with regard to the engineering process of a company manufacturing prototype machines. Now, at the end of the study and with some implementation of the advise, one might try to summarize the experiences.

The benefits of SIF are obvious. It is of essential importance that the main customer requirements are clear and agreed upon as soon as possible. To attain this goal a number of essential questions is to be discussed with the customer in a structural manner. This is the essence of SIF.
SIF should be filled out by the Weld–Equip employee who contacts the customer first. However, it is also possible that SIF (filled out or not filled out) is handed over to the customer, with Weld–Equip's friendly request to fill it out as good and complete as possible or to review SIF, being filled out (consensus). It is the Sales department's responsibility that SIF is filled out in a satisfying way.
Although in 1994 only 4% of the received enquiries was accompanied with a filled out SIF, from the re–introduction in March and April 1995 until June 1995 this percentage rose to 71% (May 24, 1995; see appendix 20 for more details). The remaining 29% was not accompanied by a sufficiently filled out SIF. Although several reasons were mentioned (enquiry was (almost) equal to a system delivered in the past; enquiry was relatively small), SIF still had to be filled out.
To reach the situation that 100% of the systems enquiries is accompanied by a sufficiently filled out SIF, regular checks (e.g. every 2 months) whether the form is still sufficiently used, are indispensable.

QMAP is the sequel of SIF: among other things SIF determines the system's main function. Next QMAP details and divides this main function into subfunctions.
The Project Co–ordinator is responsible that QMAP is applied. However, this does not mean that the Sales department never has to deal with QMAP. QMAP's should be made as early as possible and preferably before commitments are offered. Whenever the Sales department makes a first version of QMAP this will have supporting advantages for the project team.
QMAP not only has a positive influence on the communication within Weld–Equip in general and between Weld–Equip and the customer; QMAP helps to approach, analyze and lay down problems in a more functional structured manner: it is to be seen as an engineering tool, perhaps as the only readily available for customer order–driven engineering processes..
When considering all advantages and/or driving forces of QMAP, presented in this report, one might conclude that QMAP application in Weld–Equip's engineering process is required or at least desired for successful prototyping.

QMAP is a valuable tool for Weld–Equip. However, for the time being, it is not yet as a company standard. Reasons are:

- Weld–Equip's actual workload is extremely high. The market is recovering resulting in an overload of enquiries and orders. However, successful organisational change does require time and effort. That is the main reason why implementation is not executed completely yet. However, one should mention that changing and improving the present situation will also result in a more effective use of time and therefor will pay back in short term or long term

- the QMAP method is an engineering tool. This means that the project team is responsible of applying QMAP. However this project team does not exist yet and is being created right now. Creating a project team is not a purely formal activity: informal processes play an important role. This team building is a change process that needs time

To ultimately implement the QMAP method, the following actions have to be effected:

- several extra real life enquiries are to be worked out with the QMAP method (pilot projects)
- at least two Weld-Equip employees are to take a leading role in promoting and applying the QMAP method
- on the job training is necessary. Training with regard to functional deployment and using graphical software: e.g. DrawPerfect)
- QMAP diagrams are to be constructed or adapted by at least two project team members. Preferable are the Project Co-ordinator and the specific project's leader
- next every resulting QMAP diagram is to be discussed in the project team and the customer, and agreed upon
- a more detailed evaluation of the QMAP method could be desirable (e.g. inquiry)

The QMAP method is relatively simple and basic. Consequently, *extensive* training programs are not necessary; the method is best learnt by doing (on the job training).

The assignment being formulated as follows: "The design of a practical method for profitable systems manufacture, tuned to the actual product market combinations of Weld-Equip", important improvements have been implemented and advised. The change initiatives related to the VDI phase model have a few very positive effects on the problems initially encountered (see appendix 4 and 5) and on systems manufacture in general, viz.:

- improvement of internal communication
- obtaining set of product specifications quicker and better
- less iterations; consequently, time available is spent more effective and efficient
- more optimal communication with the customer
- more structured preparation of quotation
- a higher enquiry success rate
- a more profitable prototyping

Beside the VDI phase model related subjects also the administrative logistic analysis' results can considerably improve Weld-Equip's systems manufacture profitability. However, more detailed analysis, redesign and implementation is required.

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